Learn & Fly

Simulation
Module #7

Co-funded by the
Erasmus+ Programme
of the European Union

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7. Simulation
7.1 Introduction

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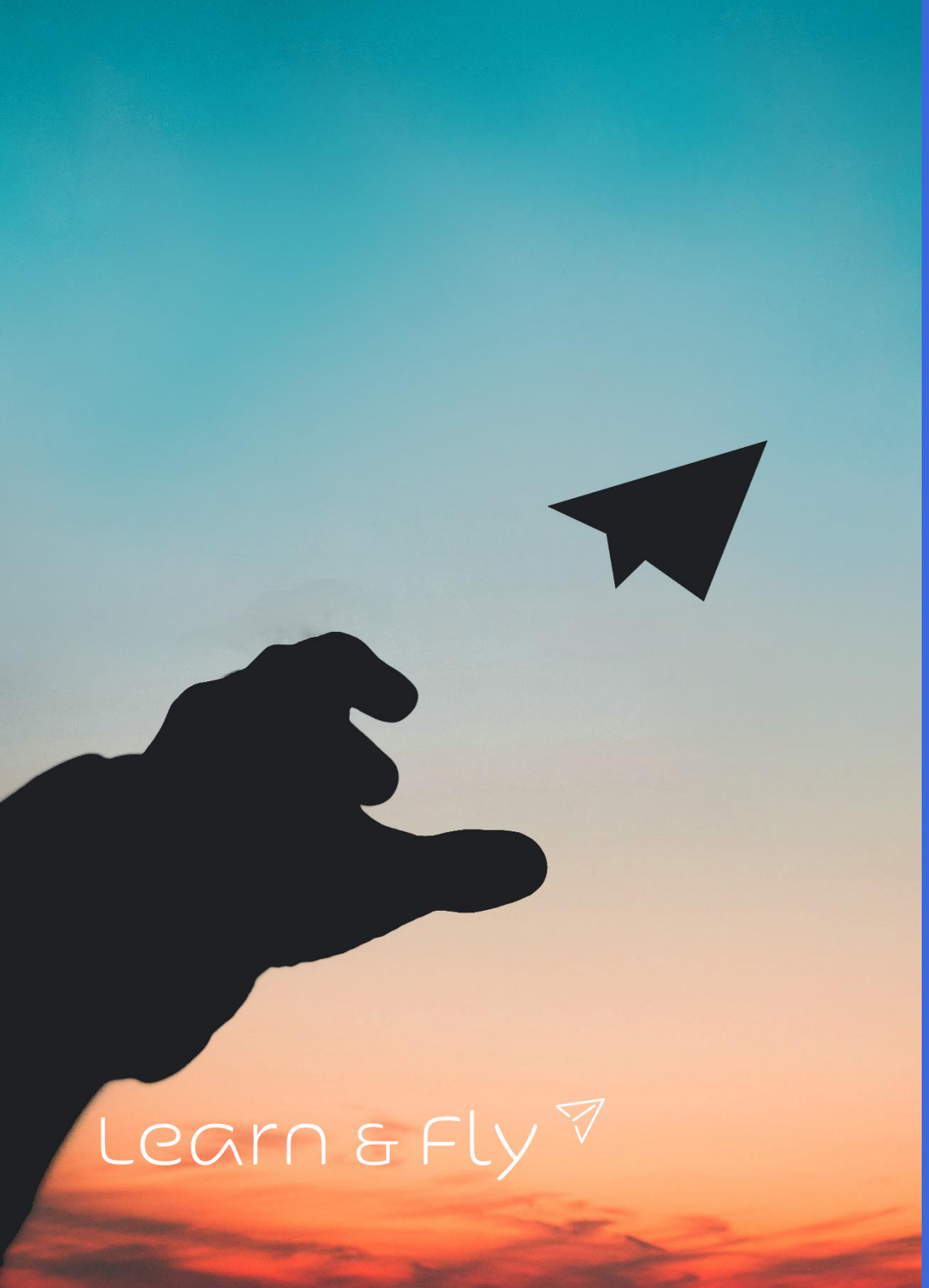

A flight simulator is a device that artificially re-creates aircraft flight and the environment in which it flies, whose main applications are:

- for pilot training,
- design and test limit situations
- for other purposes

These devices re-creates aircraft flight and the environment in which it flies

- replicates the mathematical equations that govern how aircraft fly, how they react to applications of flight controls, the effects of other aircraft systems, and how the aircraft reacts to external factors such as air density, turbulence, wind shear, cloud, precipitation, etc.

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Flight Navigation and Procedures Trainer (FNPT) Cessna 310R FNPT-I

Flight Training Devices (FTD)

https://www.alsim.com/

A350 - Full Flight Simulators (FFS)

www.cae.com

Flight simulator developed by Polytechnic Institute of Setúbal and installed at the Portuguese Air Force (Sintra – Portugal)
Video taken form TV news

Forces acting in aircraft (X-Plane simulator)

Flight simulation is used for much more than just flight training for pilots. Nowadays this is an excellent tool for design purposes, development of the aircraft itself, research and control handling qualities.

X-Plane is a powerful flight simulator also available for home users. It includes a tool called "Plane Maker" that allows the user to create their own models

- X-Plane
  - Atmosphere simulation
  - Winds and weather conditions
  - Airports, communication and orientation systems
  - Supports several languages
- Plane Maker
  - Develop your own aircrafts
  - Change the aircraft to simulate it's effects
  - Only supports English

X-Plane divides the geometry of the model (aircraft) in small elements

- Using advanced mathematics and the power of computation, the force is computed on each little element many times per second (blade element theory).
- These forces are converted into accelerations using the 2nd Newton Law:

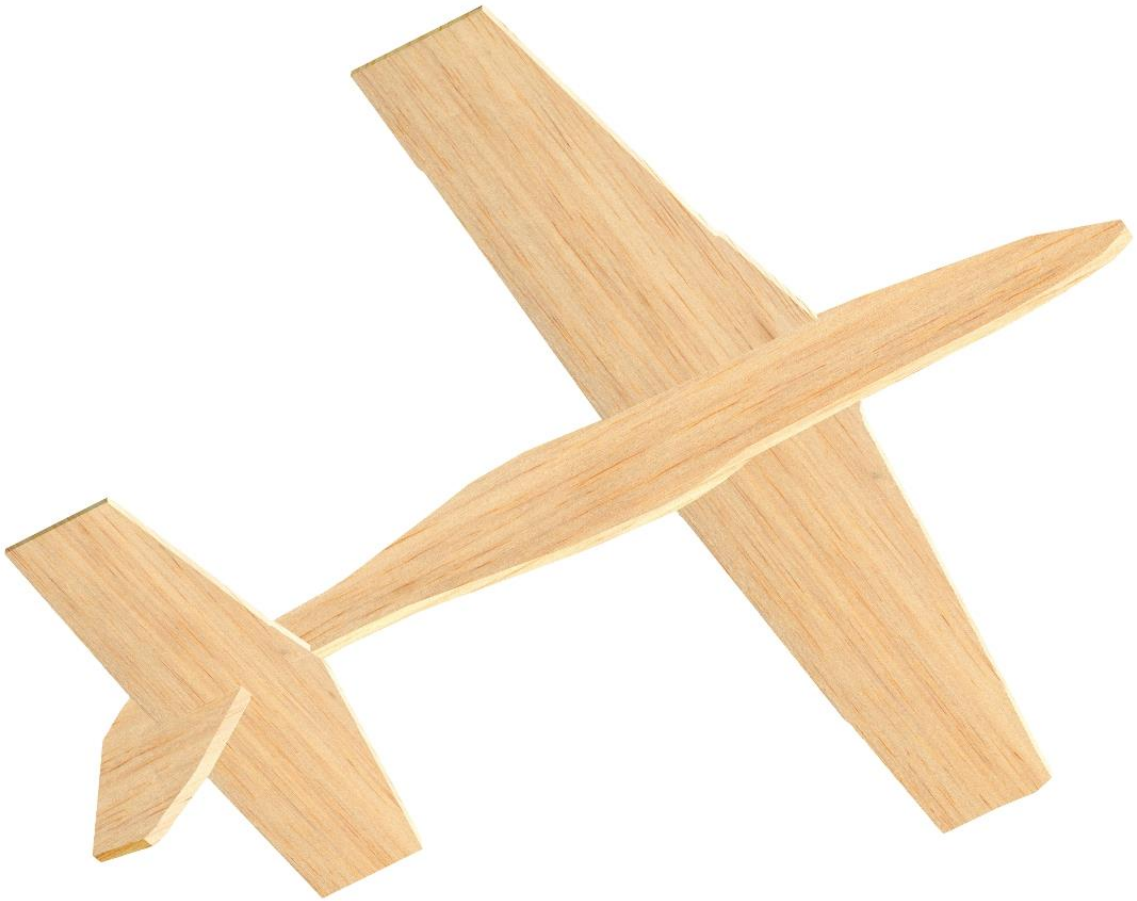
$$F = m.a \qquad (1)$$

- Knowing, accelerations is possible to find velocities and positions and the behaviour of the aircraft. This operation involves integrating the acceleration and velocity which makes part of the study programs of maths of the 1st years of engineering courses.

The package X-Plane Demo can be obtained for free from www.x-plane.com web site

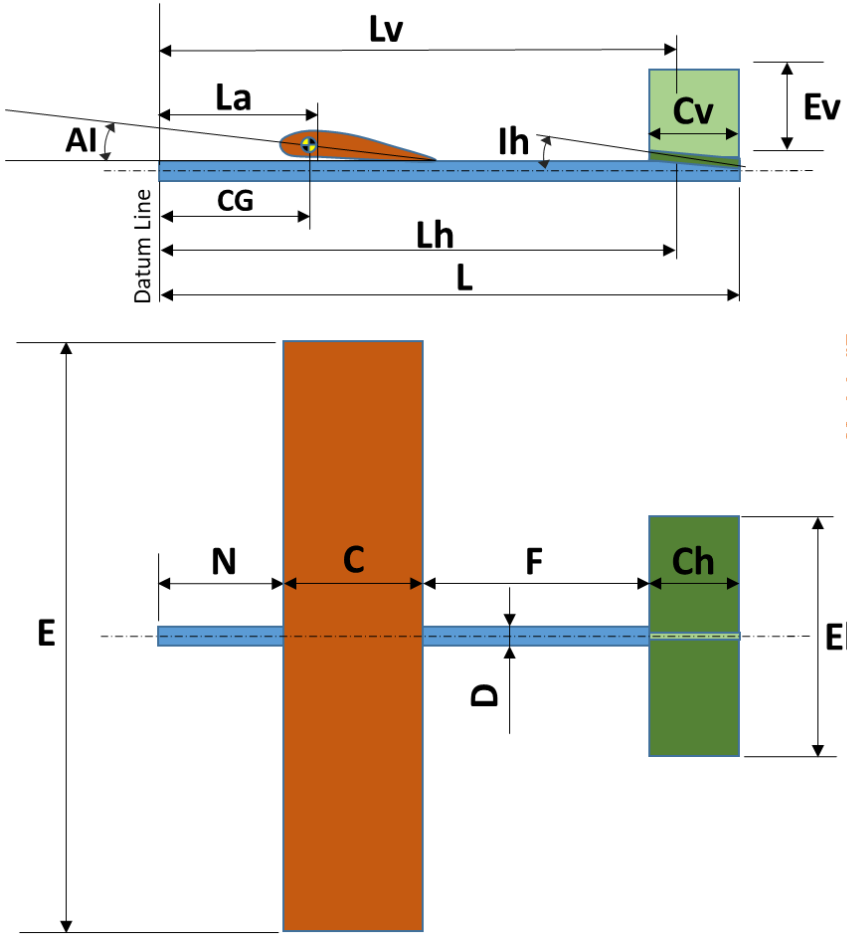
- What you can do with the Demo version
  - **get the demo up & running *(limit to 15 minutes each time)***
  - **add new aircraft to X-Plane and use Plane Maker**
  - shoot approaches to your favorite runways (demo with only one scenery)
  - test your mettle in emergency situations with failed equipment
  - customize your own airports and aircraft
  - Demo version is more than enough for Learn&Fly proposes

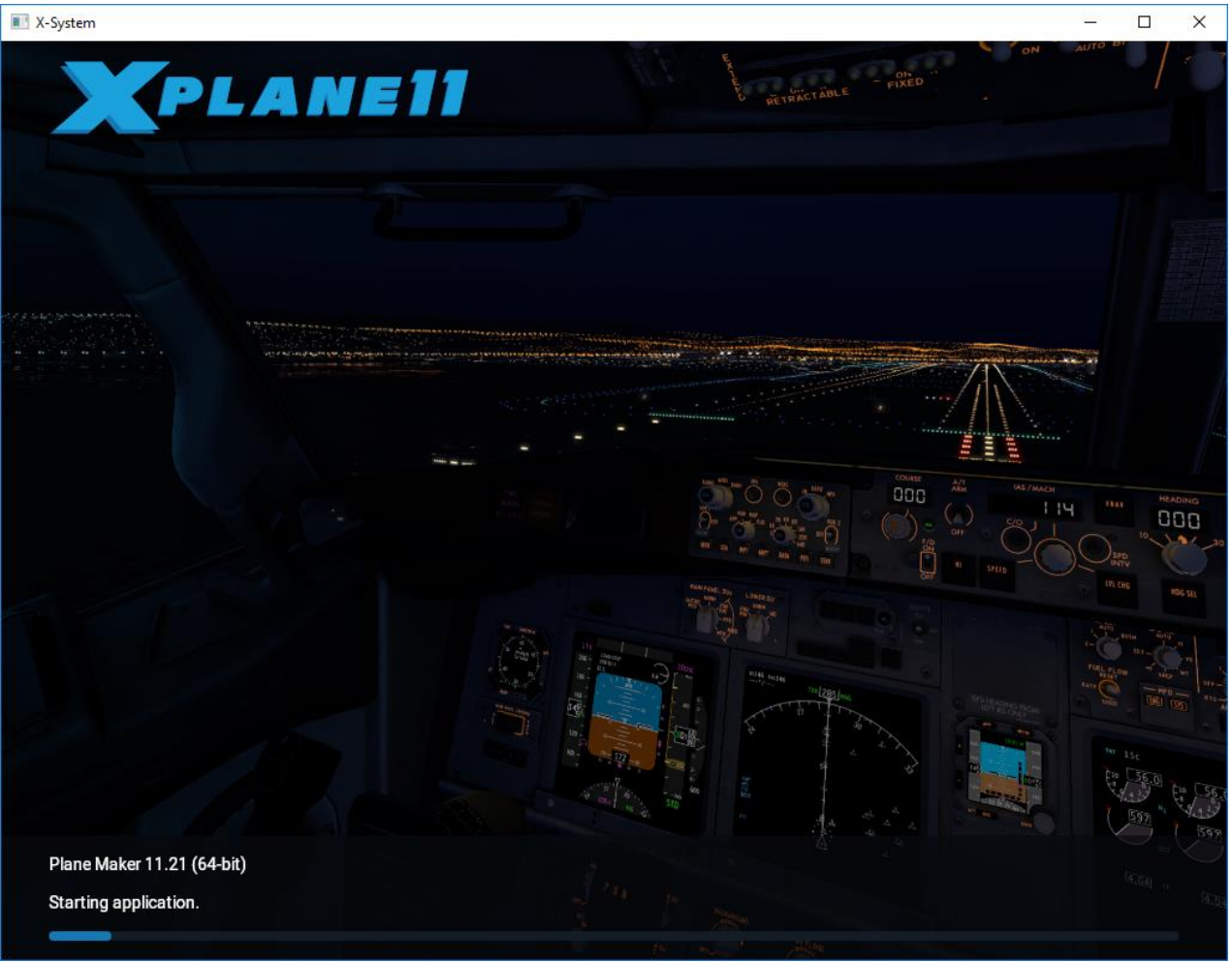
- Home users can buy X-Plane (digital download) by $69. (2018 price)
- X-Plane for professional use costs $750. (2018 price)



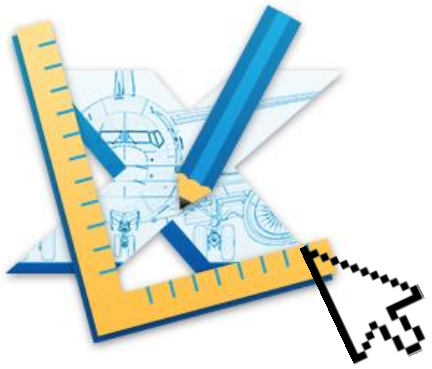
- Before starting is necessary to define your model concept
- **Section 6** provides a tool that you can use to quickly define the general dimensions of the glider
- This is only a 1st approach to have a model that flies. In the simulator you can change some of these parameters, or even the design of the glider, to obtain a better solution
- Next slide provides the basic dimensions that will be used in the model for the simulation

	Symbol	Dim. [mm]	Dim [in]	Dim [feet]
Wings				
Root Chord (C)	C	110	4.331	0.361
Length (if glider 8 to 10C or more)	E	909	35.79	2.982
Incidence angle of wing (2° to 5°) [°]	Al	2		
Longitudinal position of wing (N + 1/4 C)	La	138	5.425	0.452
Area of main wing (C x E) [unit]^2	A	99990	3937	328.1
Fuselage				
From wing leading edge to nose (1C)	N	110	4.331	0.361
From wing tail to leading edge of stabilizer (1,5 to 2C)	F	220	8.661	0.722
Fuselage total length (N+C+F+Ch)	L	523	20.57	1.714
Fuselage diameter	D	20	0.787	0.066
Horizontal stabilizer				
Chord of horizontal stabilizer (2/3 to 3/4 of C)	Ch	83	3.248	0.271
Lenght of horizontal stabilizer (2 to 2,5C)	Eh	275	10.83	0.902
Incidence angle of horizontal stabilizer (0° to 5°) [°]	Ih	-1		
Longitudinal position of horizontal stabilizer	Lh	460	18.11	1.509
Vertical stabilizer				
Chord of vertical stabilizer (3/4 to 1C)	Cv	83	3.268	0.272
Height of vertical stabilizer (1C)	Ev	110	4.331	0.361
Longitudinal position of vertical stabilizer	Lv	465	18.31	1.526
Control Surfaces (optional)				
Chord of horizontal stabilizer (1/3 of stabilizer chord)	Clp	36	1.429	0.119
Chord of vertical stabilizer (1/2 of stabilizer chord)	Cld	55	2.165	0.18
Aileron chord (1/3 of C)	Cla	36	1.429	0.119
Aileron length (2C)	Ela	220	8.661	0.722
Centre of gravity position (CG) (N + 1/4 C)	CG	135	5.315	0.443





Run the application “Plane Maker.exe” after installing X-Plane package



- Start a new project
- Identify the project, author & type of aircraft
- Provide general information for the aircraft
- Define the fuselage
- Define the wings, horizontal and vertical stabilization
- Define landing gear
- Weight & Balance
- Optional
    - Define controls
    - Create a cockpit
    - Paint your aircraft

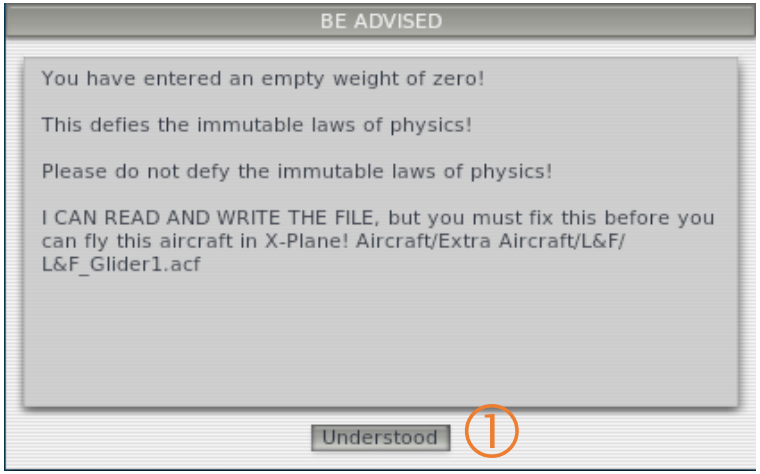
START A NEW PROJECT

After opening Plane Maker, open the File menu and click **New** to create a new aircraft

- Plane Maker will create a new aircraft only ½ of a cylindrical fuselage.

(Plane Maker only allows English language as interface)

SAVE THE PROJECT

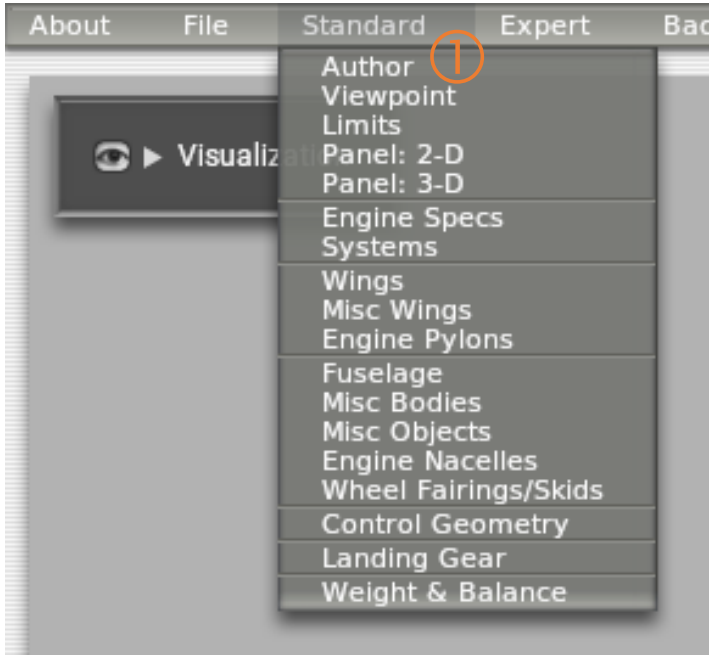


Before saving it is recommended to create a new folder for the L&F project in your file browser (Windows Explorer, Finder, etc.).

\X-Plane 11\Aircraft\Extra Aircraft\L&F

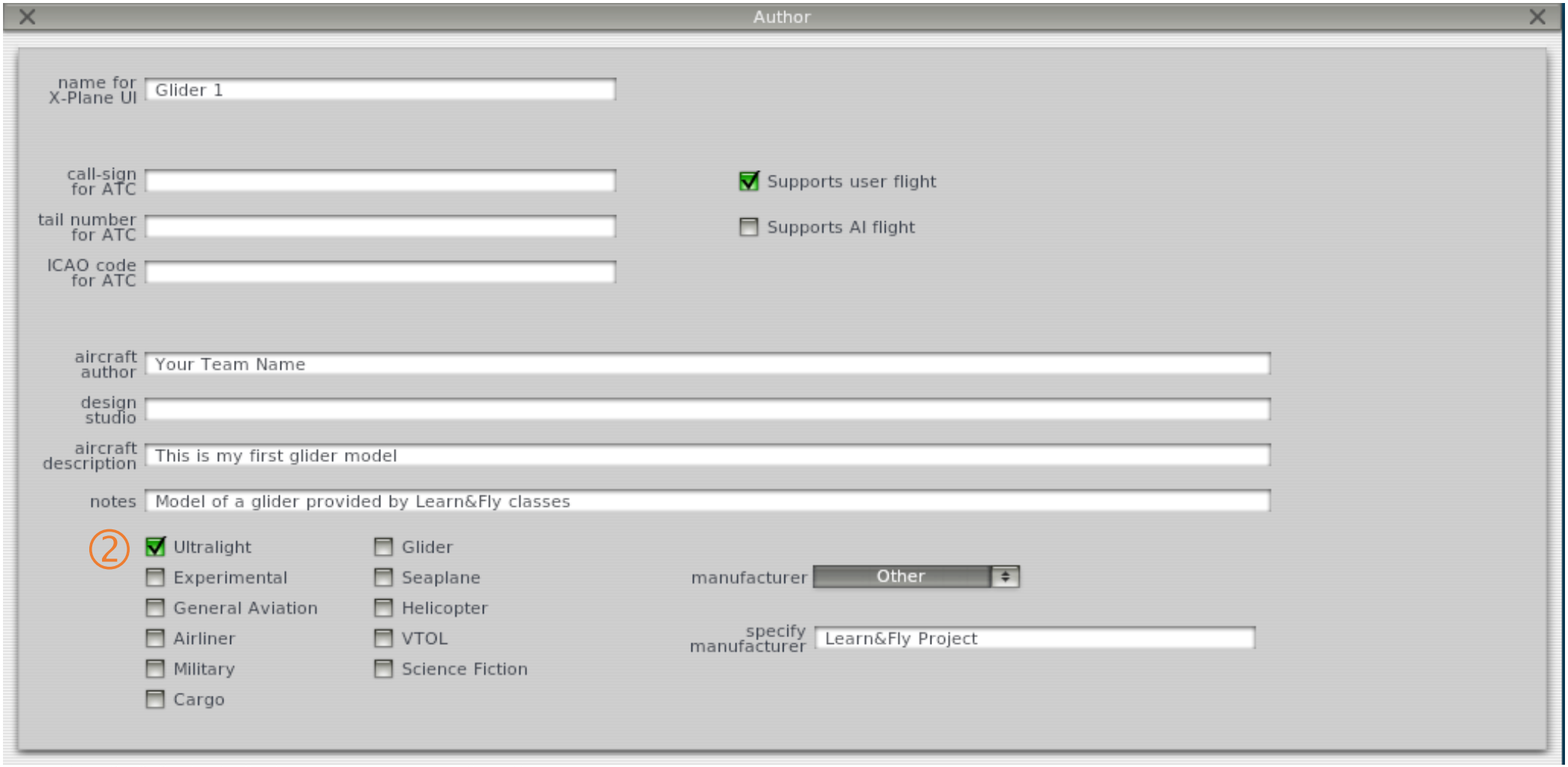
- Click File –> **Save As**, choose the folder and the name for the aircraft
  Example: **L&F_Glider1**
- After saving it may appear an advice message saying that some parameters are missing. Click **Understood** ① and don't worry because this is normal at this point.

IDENTIFY THE PROJECT



Open the Standard menu and click **Author** ①

- You should fill the fields as many as possible
- For the aircraft type select **Ultralight** ② (see next slide). We know that your model is a glider, but if you select it X-Plane will provide a winch to put the glider in the air
- In your case we will lunch the glider by hand, given an initial velocity to it

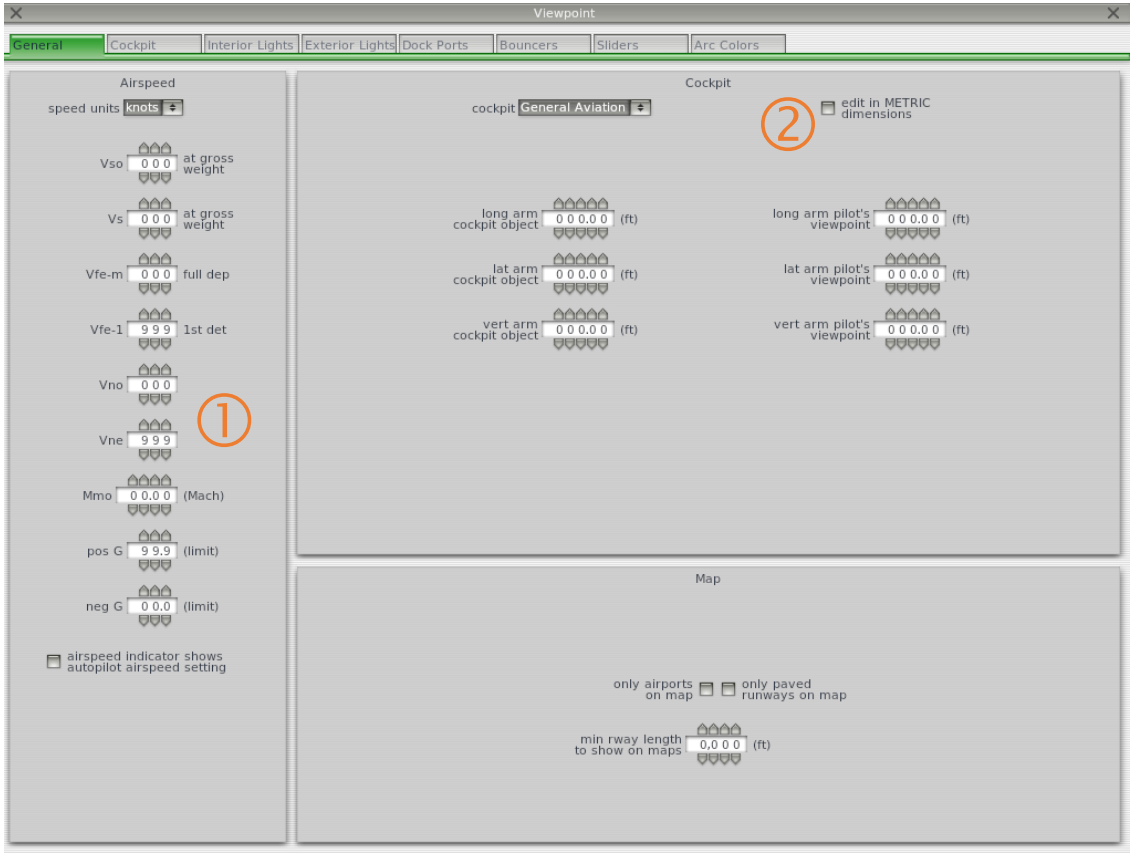

Author
name for X-Plane UI
Glider 1
call-sign for ATC
tail number for ATC
ICAO code for ATC
Supports user flight
Supports AI flight
aircraft author
Your Team Name
design studio
aircraft description
This is my first glider model
notes
Model of a glider provided by Learn&Fly classes
2
Ultralight
Experimental
General Aviation
Airliner
Military
Cargo
Glider
Seaplane
Helicopter
VTOL
Science Fiction
manufacturer
Other
specify manufacturer
Learn&Fly Project

X-Plane requires that the user introduces the maximum allowable speed (Vne) of the aircraft

- the airframe will fail if this speed is exceeded by more than about 25% the Vne

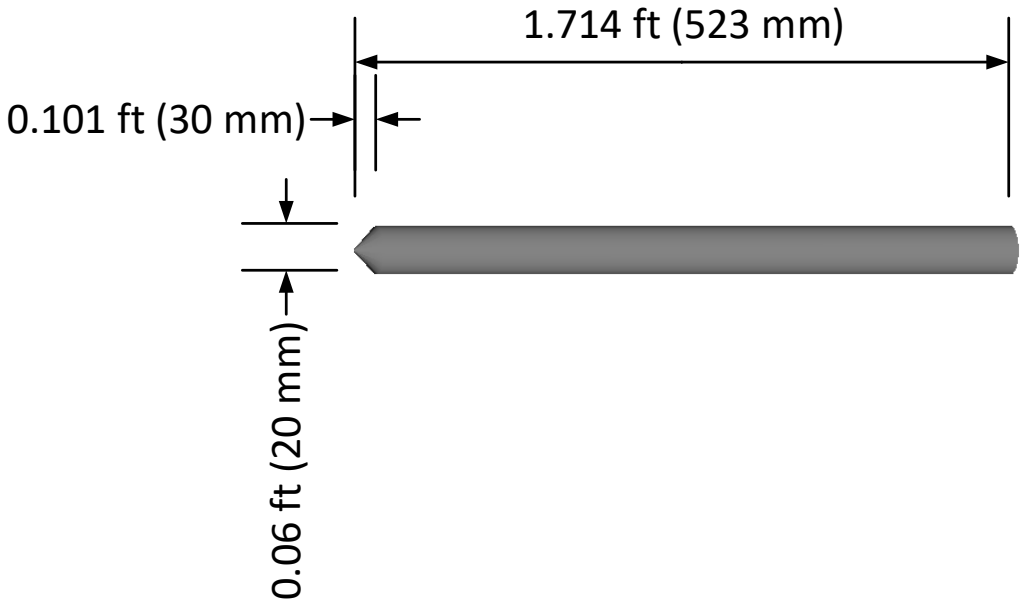
- Click Standard –> **Viewpoint**
- As this is not important for the simulation you can put **Vne=999 (knots)** ①
- In general in aeronautics is usual to work in the imperial unit or US customary system. In Plane Maker you can select the metric system (SI). We unselected this option to work in imperial units ②. You are free to select the units you want

You do not need to fill in anything else to run the model, however you are free to explore all the options



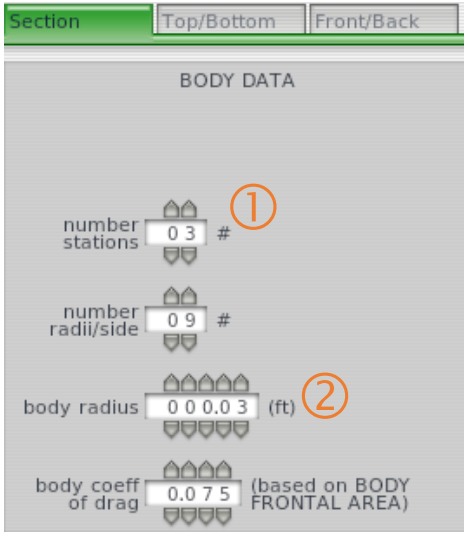
Unit	Metric System (more usual in Europe)	Imperial Units and US customary (quite usual in aeronautics)	Conversion factor from Imperial or US customary to Metric
Length	Millimetre (mm)	Inch (in)	25.4 mm/in
Length	Millimetre (mm)	Foot (ft) (12 inch)	304.8 mm/foot
Volume	Litre (l)	Gallon (US) (gal)	3.785 l/gal
Volume	Litre (l)	Gallon (UK) (gal)	4.546 l/gal
Mass	Kilogram (kg)	Pound (lb)	0.4536 kg/lb
Force	N (Newton)	Pound-force (lbf)	4.448 N/lbf
Speed	Kilometre hour (km/h)	Knot (kn)	1.852 km/h / kn
Pressure	HectoPascal (hPa) or (mBar)	Inch of Mercury (inHg)	33.86 hPa/inHg
Pressure	HectoPascal (hPa) or (mBar)	Pound/square inch (PSI)	68.95 hPa/PSI

- The fuselage dimensions were defined in section 7.3.1
- In this case we will add a beak in the front



DEFINE THE FUSELAGE

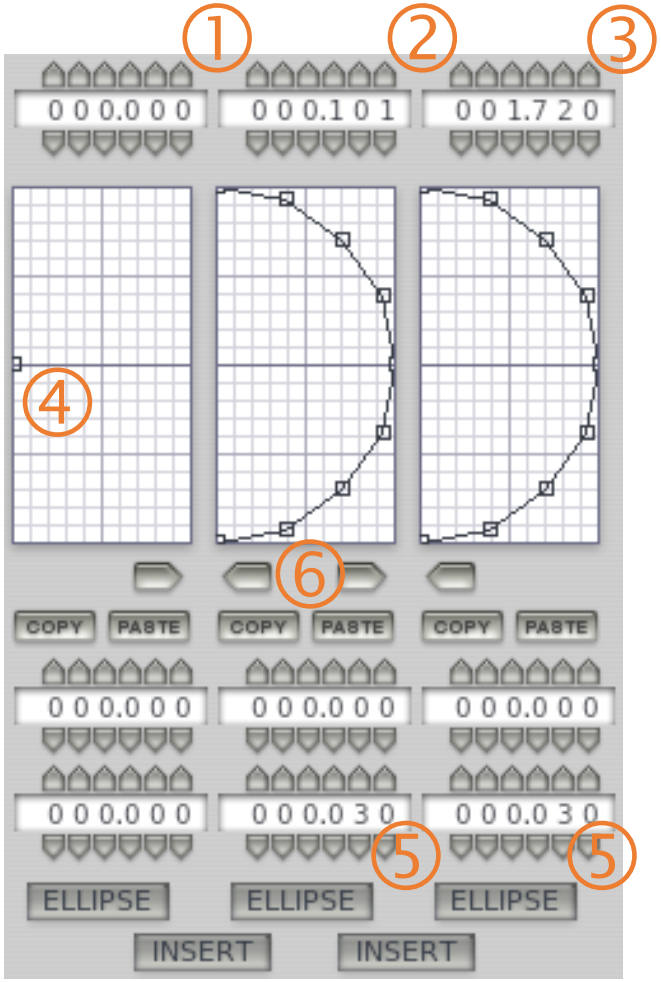
- Click Standard –> **Fuselage**
- The fuselage is created by defining the shape of several sections
- As we only have a tube we select 3 sections (the minimum Plane Maker supports)
- Parametrize **3 sections** ①
- Give the Body Radius the D/2 value **0.03 ft** (section 7.3.1)



COORDINATE SYSTEM

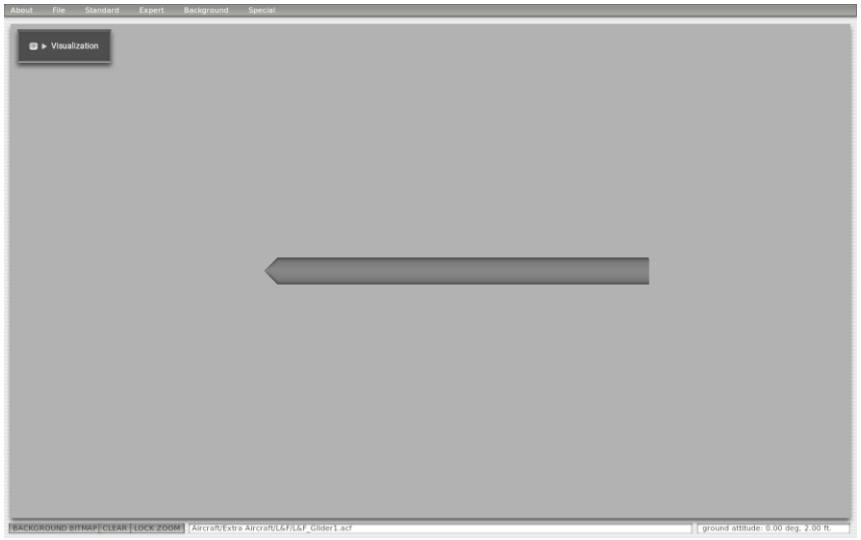
- Plane Maker has a nomenclature to position all the elements
  - Longitudinal arm
  - Lateral arm
  - Vertical arm
- Our reference point is the nose centre

- In the Cross-Sections region of the window you can parametrize the shape and positions of the sections
- As fuselage in general is symmetric, Plane Maker lets you define only half section, in this case half circle (tube)
- Each column refers to each section
  - The first parameter is the longitudinal position of the section
  - The drawing below is half section geometry in each section
  - Items bellow are tools to define the geometry
- In ①, ② and ③ define the longitudinal positions of the sections
  - ① **0 ft**; ② **0.101 ft** (just to define a beak); ③ **1.714 ft** (size L, total length)
- For the first section, move all the points to the centre, to define a unique point ④
- Second and third sections, just press the ellipse bottom to fit the shape to a circle ⑤ .You can copy and paste the 2nd section to the 3rd ⑥



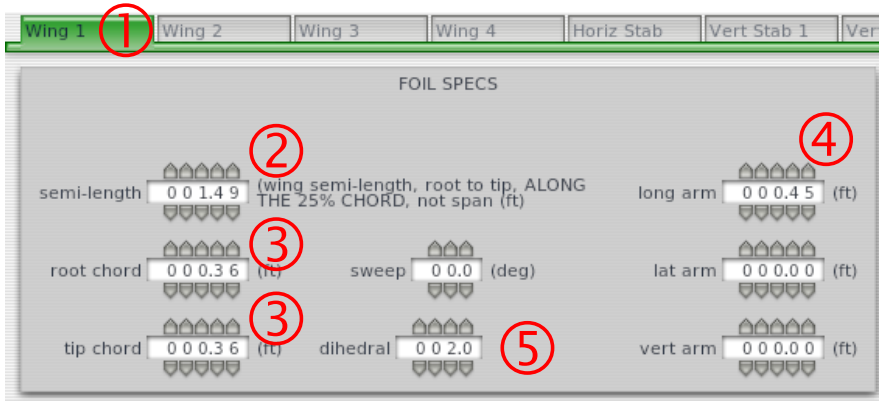
DEFINE THE FUSELAGE

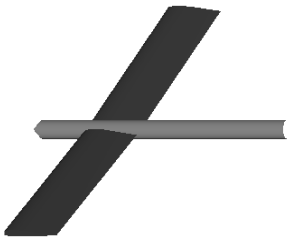
- The fuselage created in Plane Maker is as shown in figure
- Use the options provided in the Background menu to change the views or viewpoint



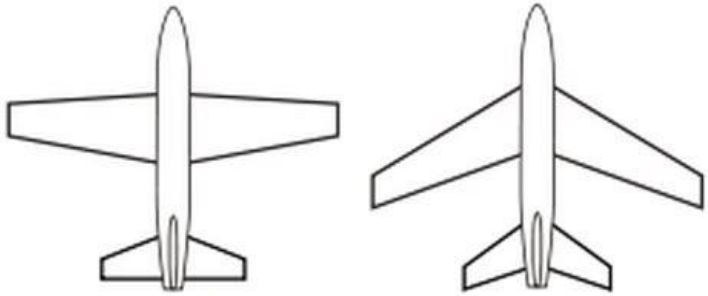
DEFINE THE WING

- Click Standard –> **Wings**
- Be sure that you are in Wing 1 tab ① and fill in these fields:
  - **semi-length =1.49 ft** (E/2=2.982/2) ②
  - **root chord** and **tip chord = 0.36 ft** (C)③ (this is a rectangular wing)
  - **long arm = 0.45 ft (La)** ④ (this is the longitudinal position of the wing)
  - **Dihedral = 2° (not included in the spreadsheet)** ⑤ (see next slide)
  - vert arm, for this example keep it in zero, but if you want to elevate the wing put here how much

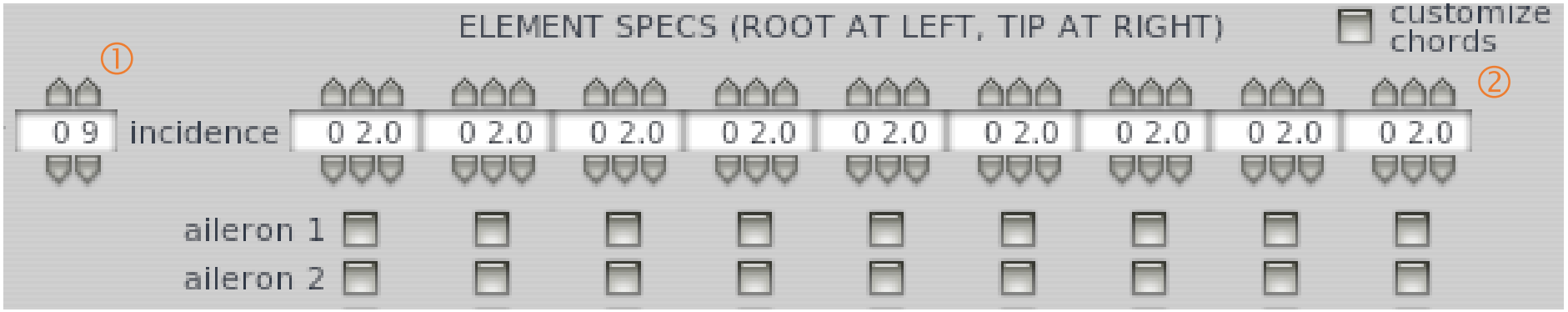




- The dihedral angle affects the lateral stability of the aircraft. As it is important that your glider flies in a straight way, you should put some dihedral angle. In this example we used 2°
- You can also configure a sweep, but this is only important for aircrafts that flies at high speed, which is not the case



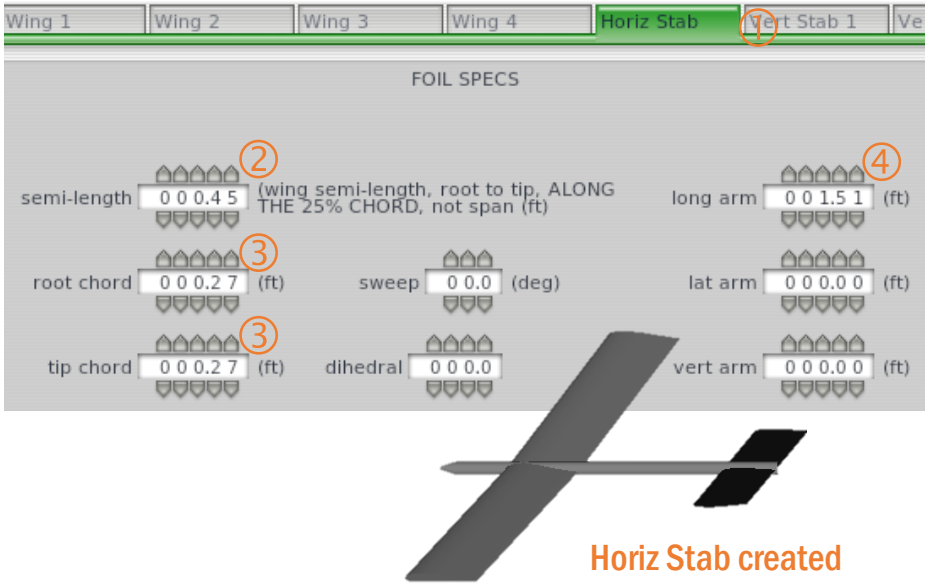
NO SWEEP SWEEP



- In the ELEMENTS SPECS window you can define the incidence angle. The wing semi-length can be divided in several parts. If you divide the wing in more parts the calculation is more accurate. In this case we will create **9 sections** ①. In each one of these parts you can configure different angles. In our case we putted **2°** (AI) for all parts ②

- In this window you can configure control surfaces. For example if you want ailerons in the last 2/9 part of the wing, put a cross in the last two boxes of aileron 1. For this example we will not create control surfaces.

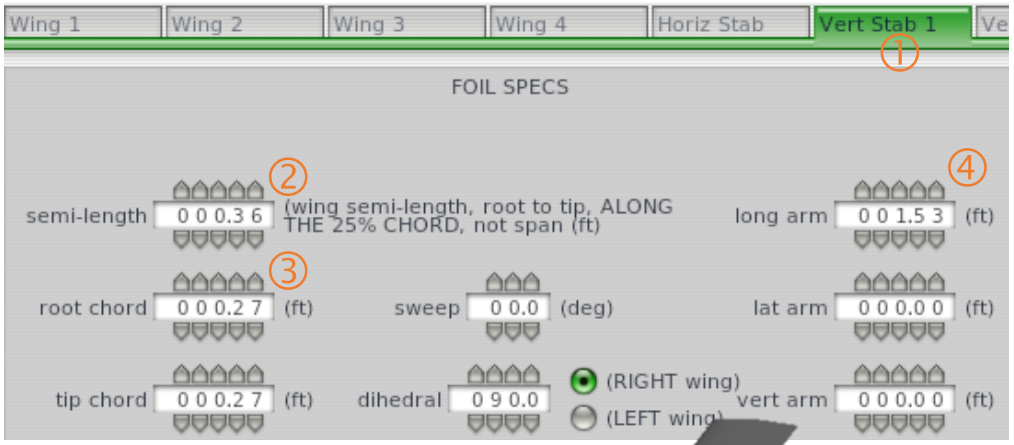
- In the menu Standard –> Wings select the **Horiz Stab** tab ① and fill in these fields:
  - **semi-length =0.45 ft** (Eh/2=0.902/2) ②
  - **root chord** and **tip chord = 0.27ft** (Ch) ③ (rectangular shape, but you may change)
  - **long arm = 1.51 ft** (Lh) ④ (this is the longitudinal position of the horiz stab)



Horiz Stab created

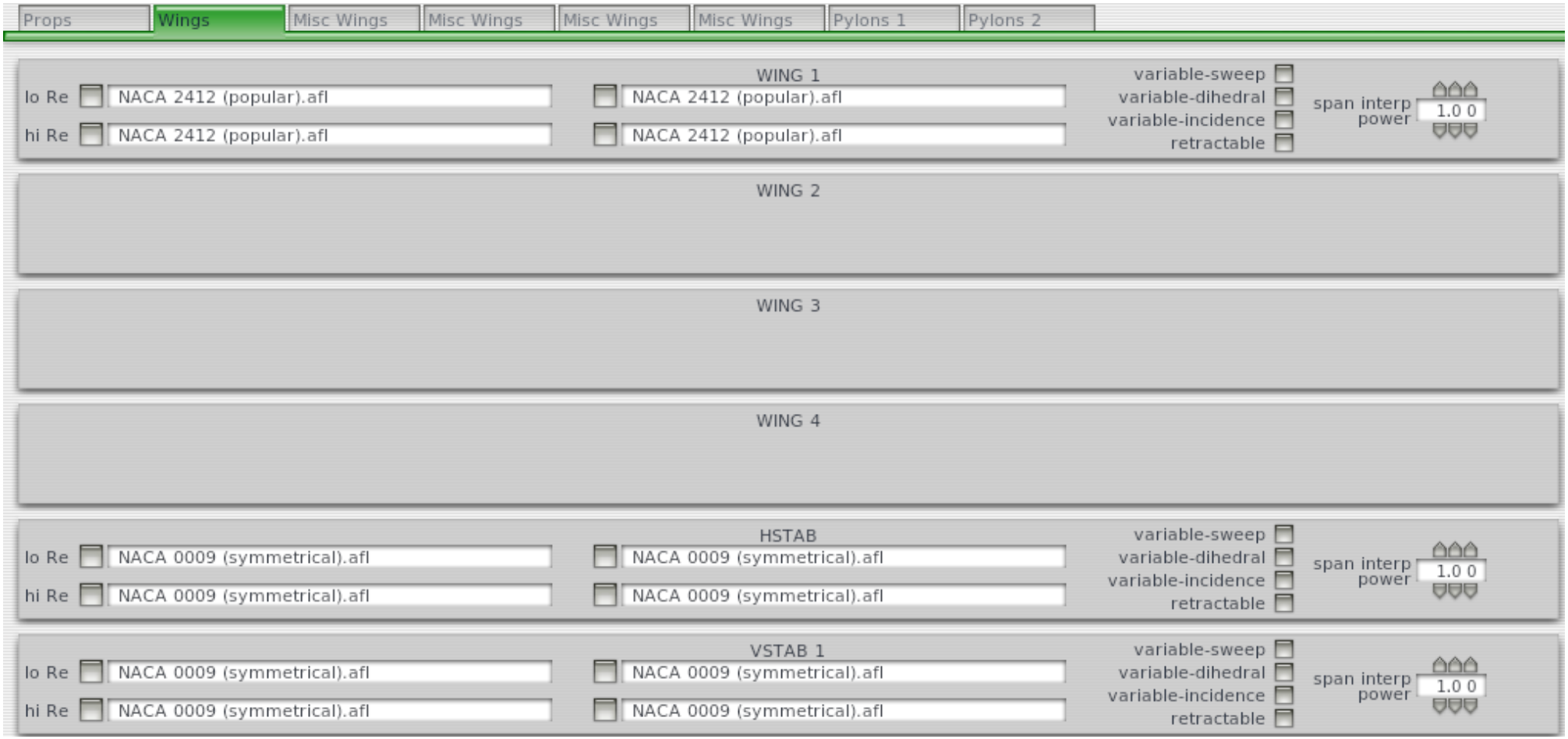
- In order to improve stability it is recommended to include a small negative incidence angle to create a small force down in the horizontal stabilizer. This will keep the glider flying horizontally, however it will increase the drag force.
- You are challenged to find the best relation between the incidence angle of the main wing and the horizontal stabilizer.
- In ELEMENTS SPECS window **create 5** sections ① and in each one of configure **-1°** (lh) of incidence angle ②.

- In the menu Standard –> Wings select the Vert Stab 1 tab ① and fill in these fields:
  - **semi-length =0.36 ft** (Ev) ②
  - **root chord** and **tip chord = 0.27ft** (Cv) ③ (rectangular shape, but you may change)
  - **long arm = 1.53 ft** (Lv) ④ (this is the longitudinal position of the vert stab)
  - Close the window

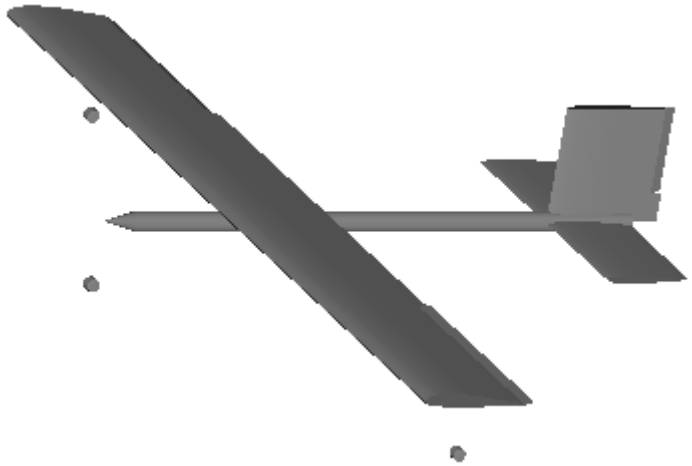


Vert Stab created

- You must choose the airfoil profile for each wing (main wing, horizontal and vertical stabilization)
- Click Expert –> **Airfoils**
- Be sure that you are in Wing tab ① (next slide) and fill in these fields:
  - For the wing 1 - NACA 2412 (popular).afl
  - For the stabilizers a symmetrical profile like - NACA 0009 (symmetrical).afl
- You can also create a new wing airfoil using the “Airfoil Maker” that is included in X-Plane. However this is an advanced feature that is outside the scope of this project, but if you want you can try it. If your profile is not available in Plane Maker, use a similar one to do your simulations.

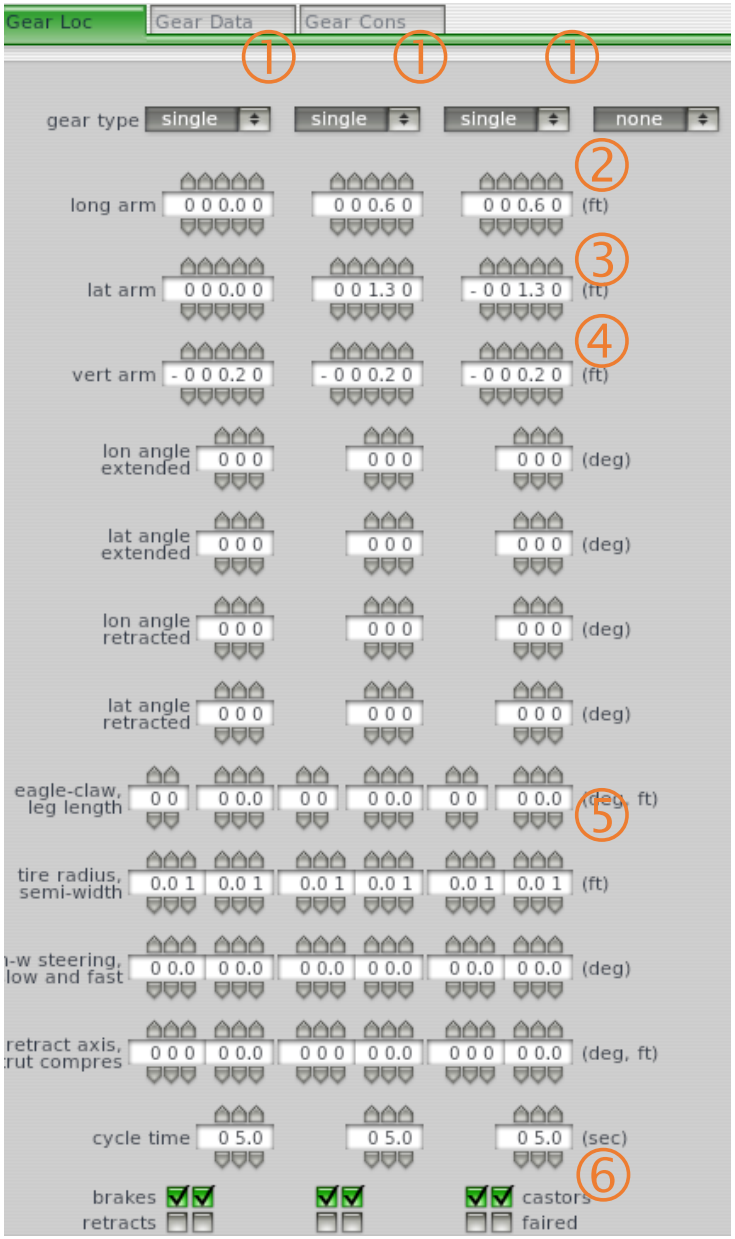

Props
Wings
Misc Wings
Misc Wings
Misc Wings
Misc Wings
Pylons 1
Pylons 2
WING 1
lo Re
NACA 2412 (popular).afl
NACA 2412 (popular).afl
hi Re
NACA 2412 (popular).afl
NACA 2412 (popular).afl
variable-sweep
variable-dihedral
variable-incidence
retractable
span interp power
1.0 0
WING 2
WING 3
WING 4
HSTAB
lo Re
NACA 0009 (symmetrical).afl
NACA 0009 (symmetrical).afl
hi Re
NACA 0009 (symmetrical).afl
NACA 0009 (symmetrical).afl
variable-sweep
variable-dihedral
variable-incidence
retractable
span interp power
1.0 0
VSTAB 1
lo Re
NACA 0009 (symmetrical).afl
NACA 0009 (symmetrical).afl
hi Re
NACA 0009 (symmetrical).afl
NACA 0009 (symmetrical).afl
variable-sweep
variable-dihedral
variable-incidence
retractable
span interp power
1.0 0

- Landing gear is not necessary for the physical model, however this is required in the virtual model to avoid X-Plane to drop it on the ground
- As these are not important for the simulation we will create one wheel in the nose of the aircraft and two other close to the end of the wing at 2/3 of the wing chord
- The wheels must be at a reasonable distance from the fuselage. In this case we will use 0.2 ft down
- Put the wheels extremely small to avoid drag force

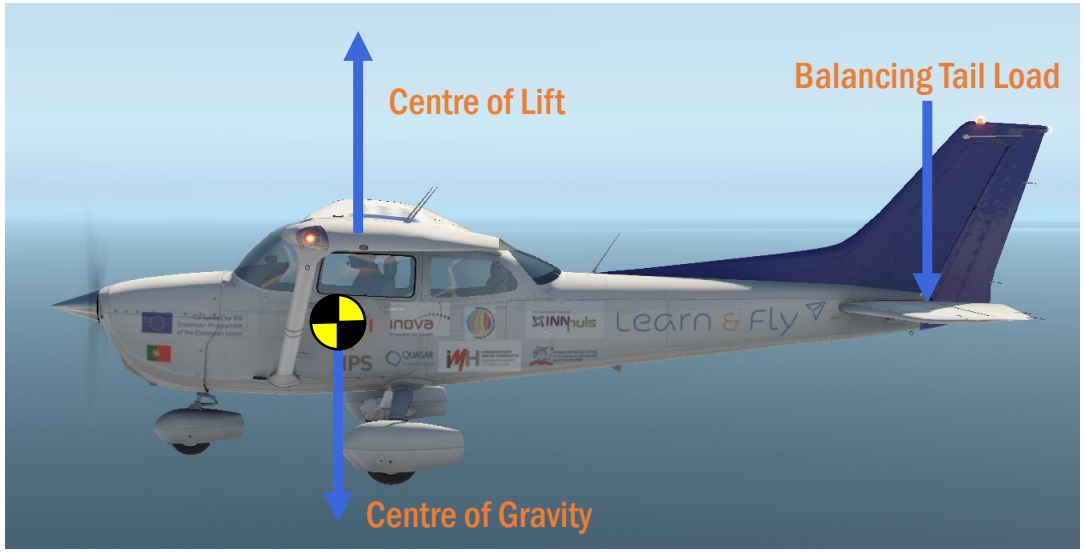


Landing gear to be created

- Click Standard –> **Landing Gear**
- Configure **3** gears type **single** ①
  - The first one will be the nose gear
  - The other two ones will be under the wings
- Parametrize as shown in the figure:
  - **long arm = 0.6 ft** ② (the last 2 at LG)
  - **lat arm = 1.20 ft** (the last 2 with a bit less than E/2=2.982/2) ③
  - **vert arm = -0.2 ft** ④ (all wheels down relative to the fuselage)
  - **tire radius =0.01 ft** (all the wheels (they are double) with the minimum allowable by Plane Maker) ⑤
  - Select breaks on all of them ⑥



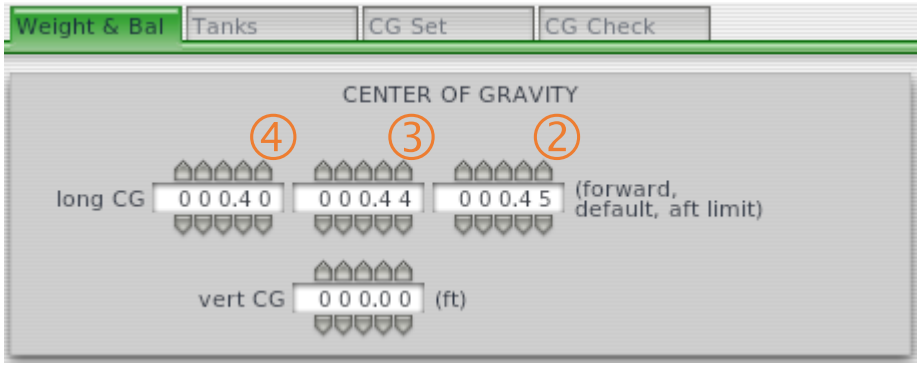
- This is the most important task when configuring your aircraft, as explained in section 3
- The CG must be near the centre of lift (CL), a bit forward to the center of pressure, to create a small pitch moment between the centre of gravity (CG) and CL. The pitching moment created by the difference in the CG and CL location must be reacted out by the horizontal stabilizer.



- Click Standard –> **Weight & Balance**
- Be sure that you are in the Weight&Bal tab ① and fill in these fields in the CENTER OF GRAVITY dialog box
  - Max. allowable position of CG = **0.45** ft ②
  - Position of CG = **0.44** ft ③
  - Min. allowable position of CG = **0.40** ft ④
    - X-Plane will allow you to change interactively the CG position during simulation, between max. and min. position of CG.

- You must also configure the weights of the aircraft in the WEIGHTS box
  - Empty weight, as first approach we will use 200g = 0.44 lb ①
  - Maximum weight 300g = 0.66 lb (added a 100g payload) ②

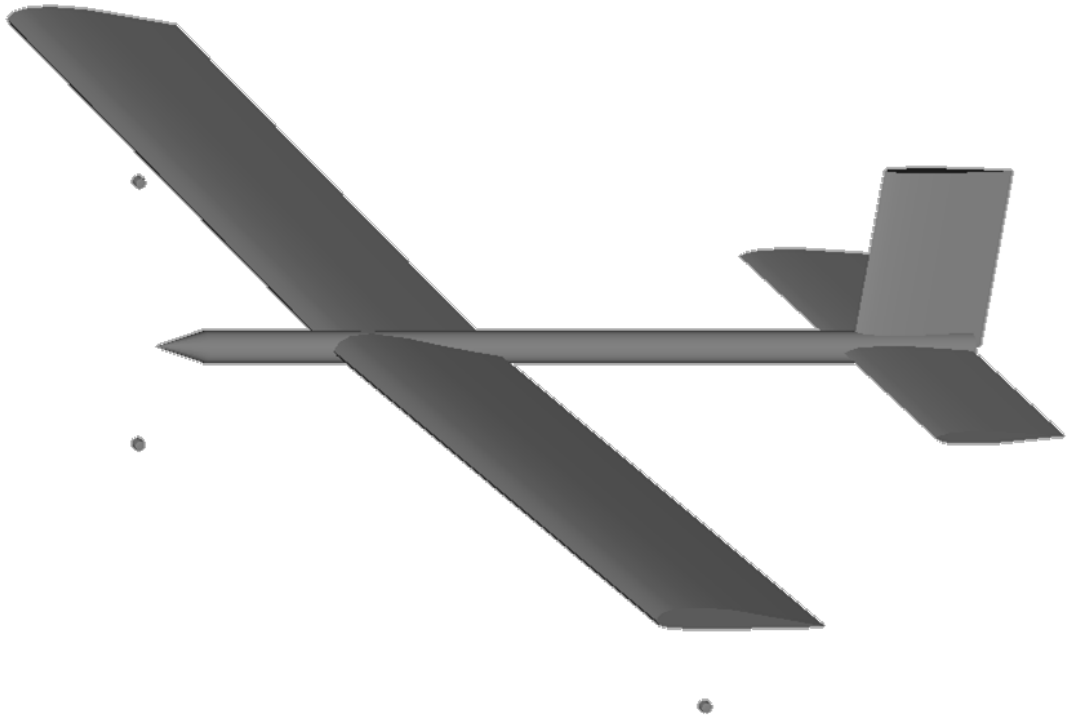
①



- You can easily create a panel to get some information about your flight
- Recommended instruments for the glider
  - Indicated air speed
    - Reading from the pilot tube generally in knot units
  - Altimeter
    - Altitude above sea level in feet units
  - Rate of climb indicator
    - Shows how much you are climbing or descending in feet/minute units
  - Artificial horizon
    - Shows what the horizon should look like from your current point of view

- Click Standard –> Panel: 2D
- From Instrument List – IOS drag and drop the next instruments to the cockpit
    - IOS_asi.png; IOS_alt.png; IOS_vvi.png; IOS_horiz.png

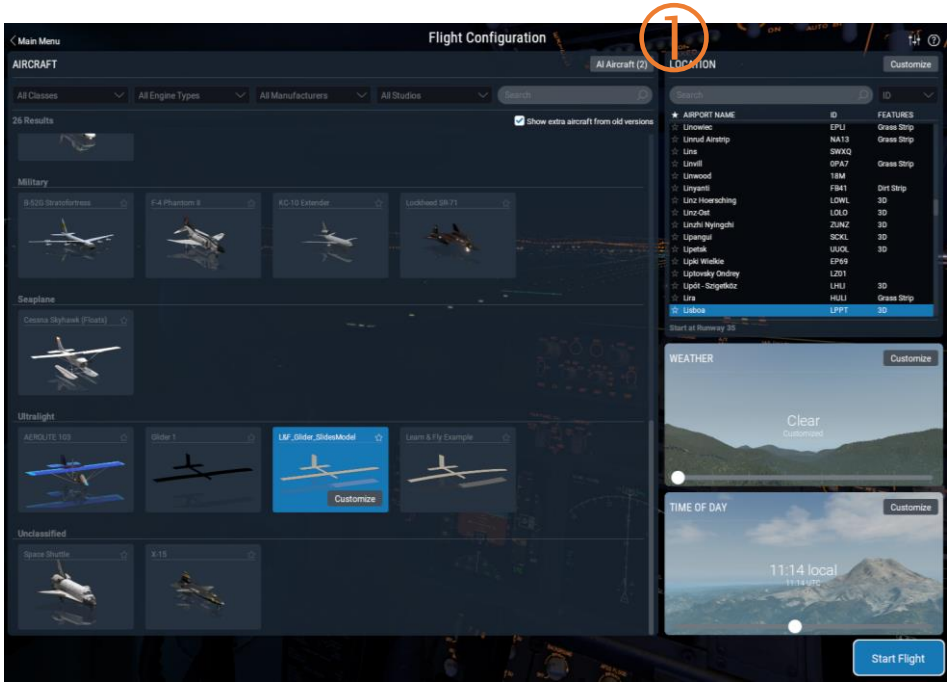
Do not forget to save your model!



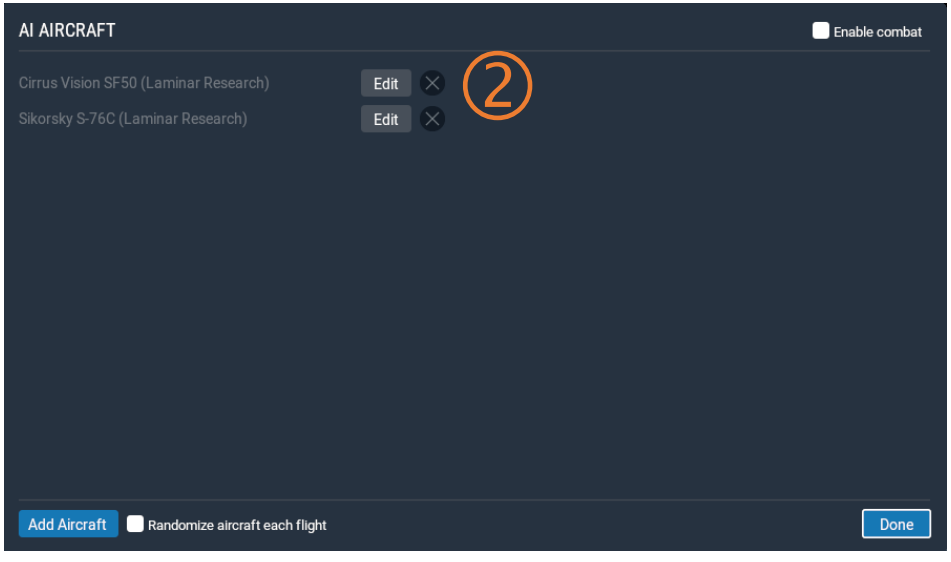
- Run the application “XPlane.exe”
- Next slides will be for version 11.25. New versions may differ slightly.
- We removed the licence CD to become like in demo version (each flight limited to 15 min.)
- When flying, X-Plane allows to define other languages in Settings - General. For this application we will demonstrate X-Plane in English.

- When X-Plane Starts select **New Flight**

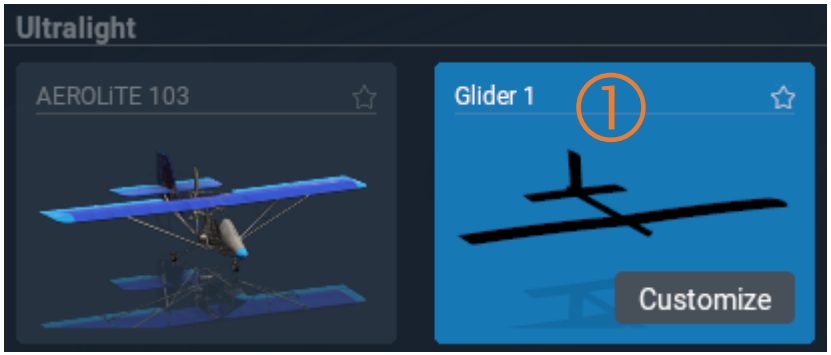
- The Flight Configuration window opens
- Select **AI Aircraft** ①



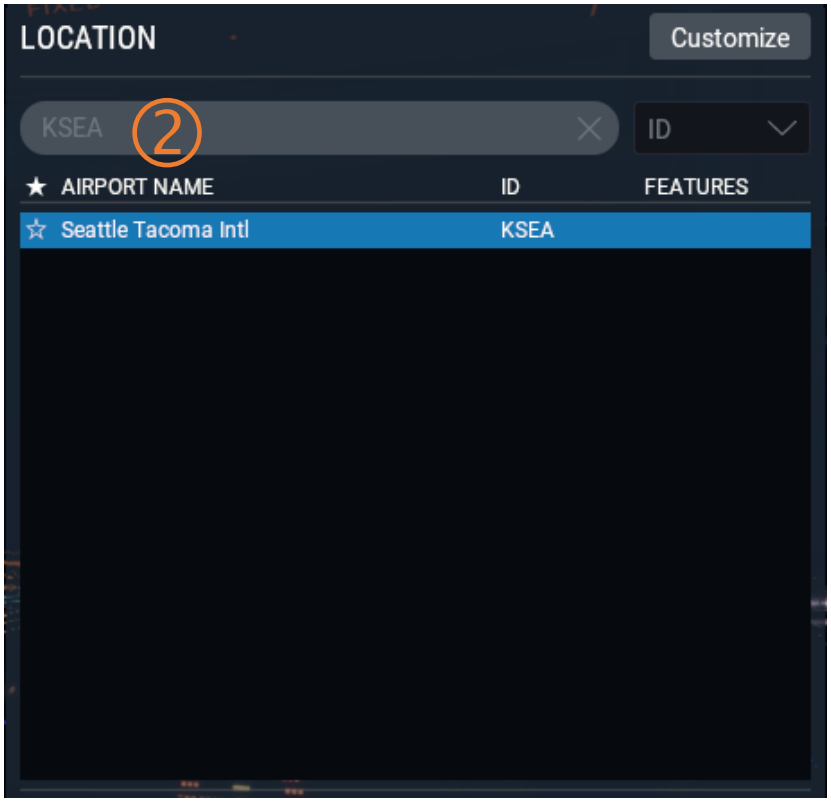
- From AI Aircraft remove any existing aircraft ②
- This will avoid that other aircrafts may interfere in the simulation
- Press Done to close the window



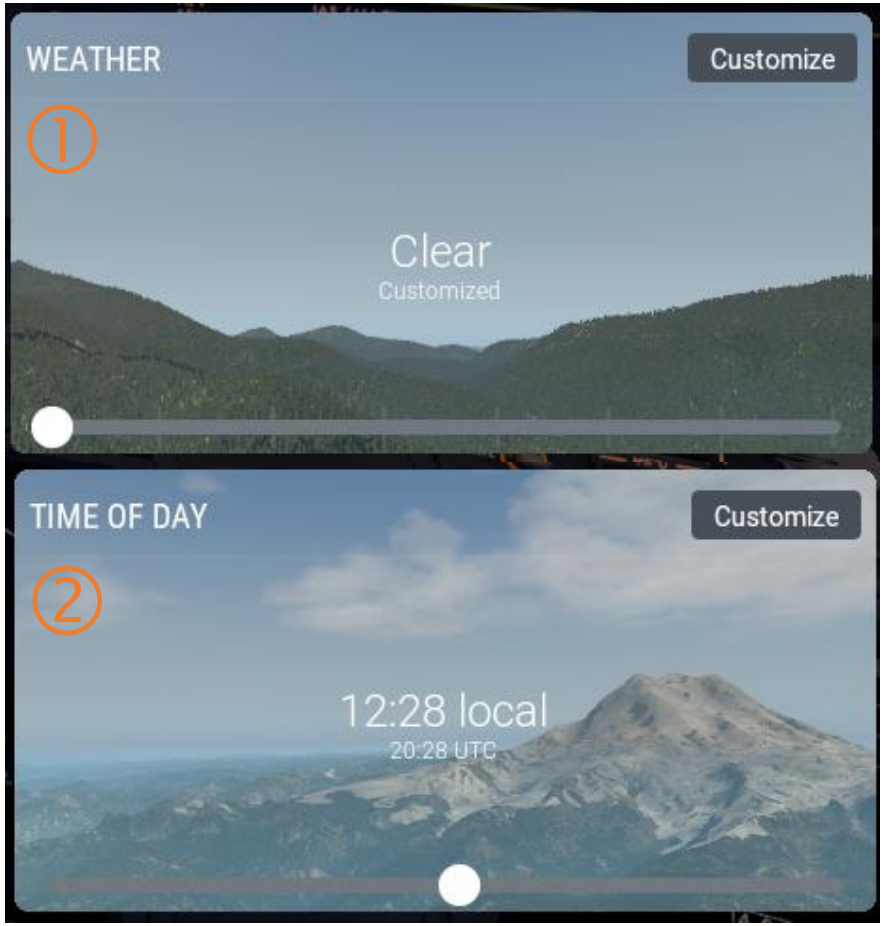
- In the Flight Configuration window select your model that is in the **Ultralight group** ①
- Your aircraft will appear with the name that you defined for "name for X-Plane UI" in X-Plane
- In our case we will select the **"Glider 1"**
    - If you click in customise you can create an icon for your model



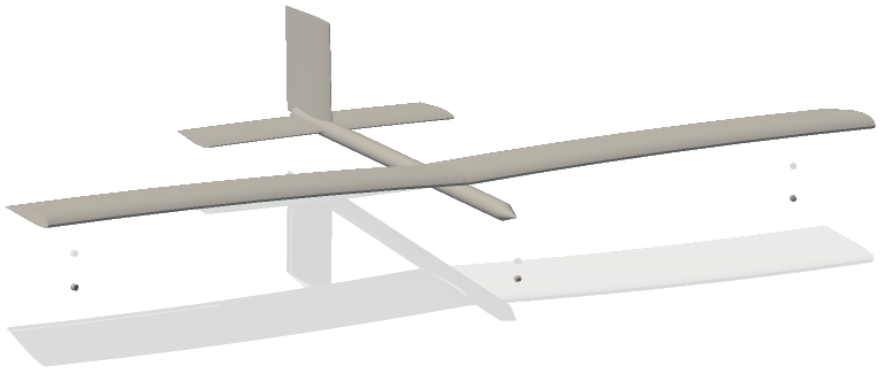
- Under **LOCATION** ② select Seattle Airport if you have the demo version (the only one available).
- If you select other airport, and have the demo version, you will find only water near the run way. This is not a limitation for the simulations we want to do but if you have graphics the simulation will be more interesting.
- You can find quickly the airport searching for **KSEA** (ICAO code of the airport)
    - ICAO is the International Civil Aviation Organization



- Under **Weather**, move the slide to the left to set **Clear**①
- Under TIME OF DAY, select a day time moving the slider to the mid ②
- Press **Start Flight** ③ to launch the glider

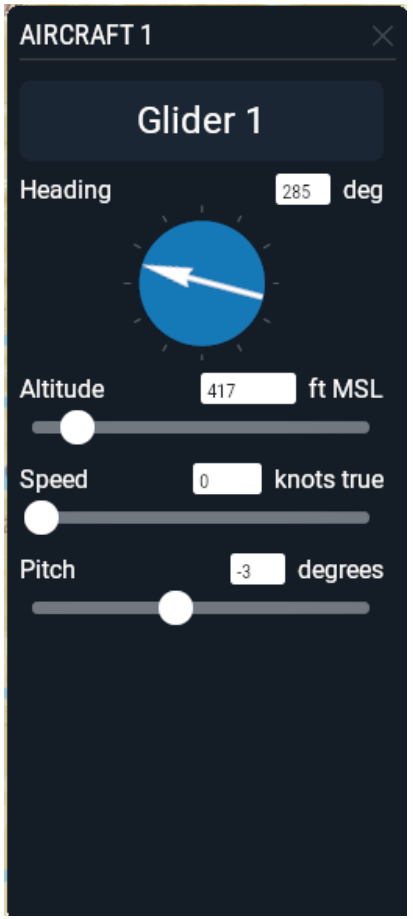


- When X-Plane starts the simulation your aircraft is in the run way. As you do not have a motor, neither a winch you need to get a way to put it in the air.
- As you are in a simulator you can virtually do almost anything, like putting the aircraft in the air at some velocity
    - Press "**p**" to pause the simulator
    - Press "**i**" to show the IOS (Instructor Operator Station) or use the menu
      Flight -> **Show IOS**
- The IOS dialog box will open, allowing you to change your flight configuration
- In the map press with the mouse under your aircraft (it should be in the middle of the map) to open the aircraft dialog box

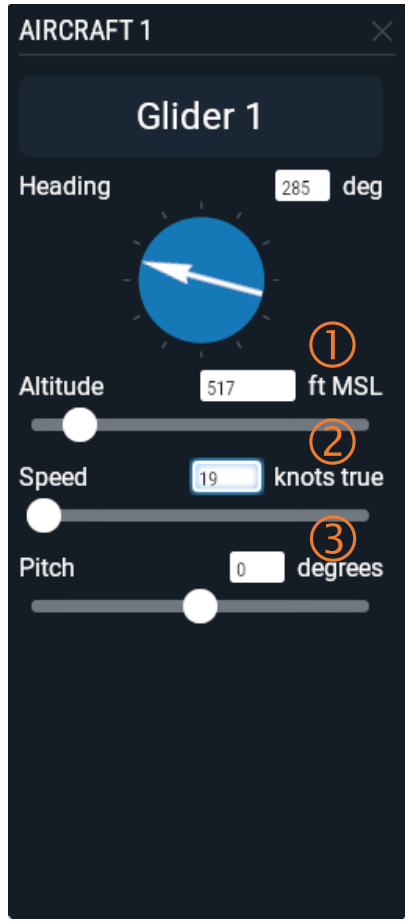


- In the Aircraft 1 dialog box you can now change the altitude, speed and pitch
- As an example you can add 100 ft (30.5 meters) to the altitude
- Put 417 (initial altitude) + 100 = **517 ft** ① in the altitude
    - The real altitude to launch the glider by hand should be about 2 meters. However the simulation will be too short to see how the glider behaves. So for simulation purposes we recommend to add 100 ft to the altitude (about 33 meters).
- Put **19 knots** ② (10 m/s) in the speed
- Put **0 degrees** ③ in the Pitch to launch horizontally
- Close all the windows, including the IOS (pressing the red dot at the top left corner)
- Press “p” to exit pause and start launching

Before



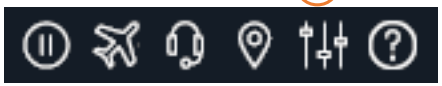
After



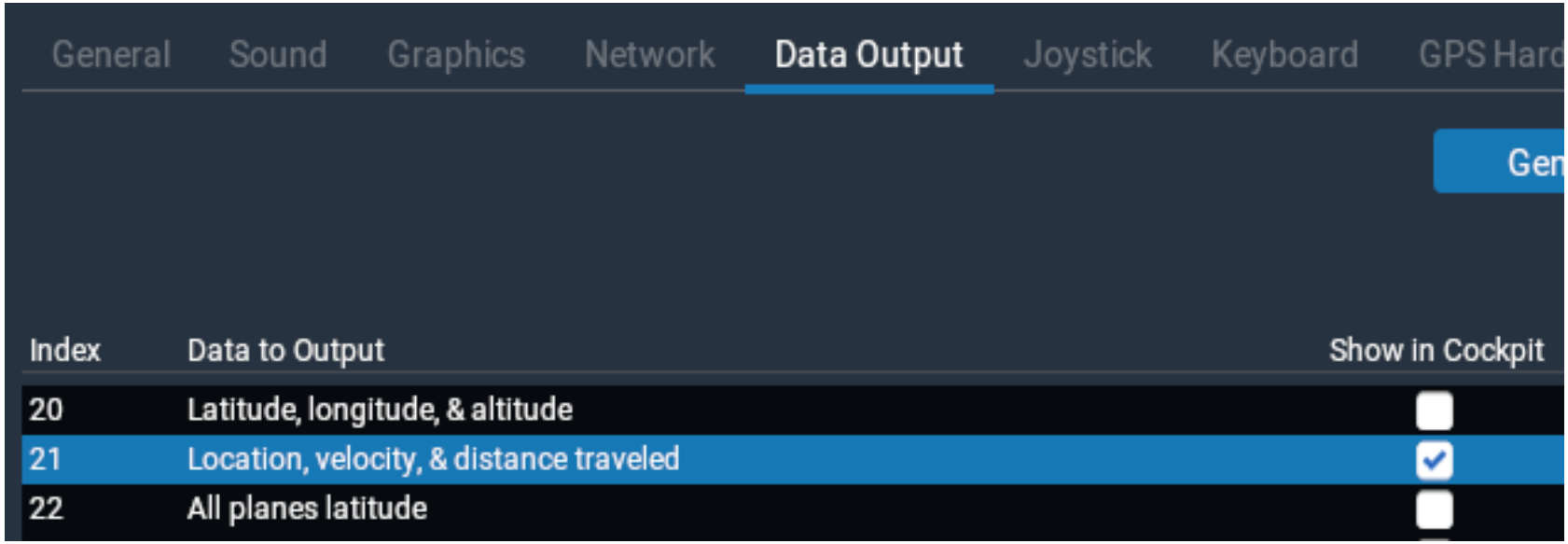
- Once your aircraft is flying you can change the views
  - w – Inside view with cockpit
    - q – rotate left
    - e – rotate right
    - r – rotate up
    - f – rotate down
    - = - zoom in
    - - - zoom out
  - W – Inside view with head up display
  - Shift +1 to 9, several outside views
- Find more about views on menu **View**

- X-Plane allows to display or save to disk flight parameters
- Pause your simulation pressing on "**p**"
- In the top right of the screen select **Settings** ①
- Select the tab "**Data Output**" ②
- Select the box **"Show in Cockpit"** index **21** ③ (Location, velocity & distance travelled)

①



②



③

- Backing to X-Plane you have in the top left of the screen the information you selected, positions, velocities and distance travelled

- Note that the distance travelled is the total distance and not the distance to the front. If your aircraft turns to one side this gives a wrong measurement, considering the measurement accounted for the Learn&Fly competition
- Now you can take notes about the distance travelled to improve the behaviour of your aircraft

- For the first time your aircraft my not behave as expected.
- If your aircraft goes too much up and down it means that possibly the centre of gravity (CG) is not in the right position
    - Press “i” and change the position of CG (you may also pause the simulation)
    - It is recommended to use metric values to allow putting the payload of 0.1 kg.
- If your model turns to much to one side and increasing dihedral angle is not solving, it may be facing some numerical problems during simulation. Try adding some control surfaces like ailerons to control the aircraft and avoid turning
- Try changing also angles and dimensions in Plane Maker and study its effect in X-Plane
    - Don’t forget to plan before make any changes
    - Register and report your tries and results

- **If your model flies well in the simulator it will have a good probability to fly also well in real world**

- Lisbon Airport (ICAO: LPPT)
  - 100 ft
  - 19 knots
  - Pitch 0 degrees
  - Payload 0.1 kg
- Glider as modelled with dihedral angle 5º
- No control surfaces

Good job!

Learn & Fly

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