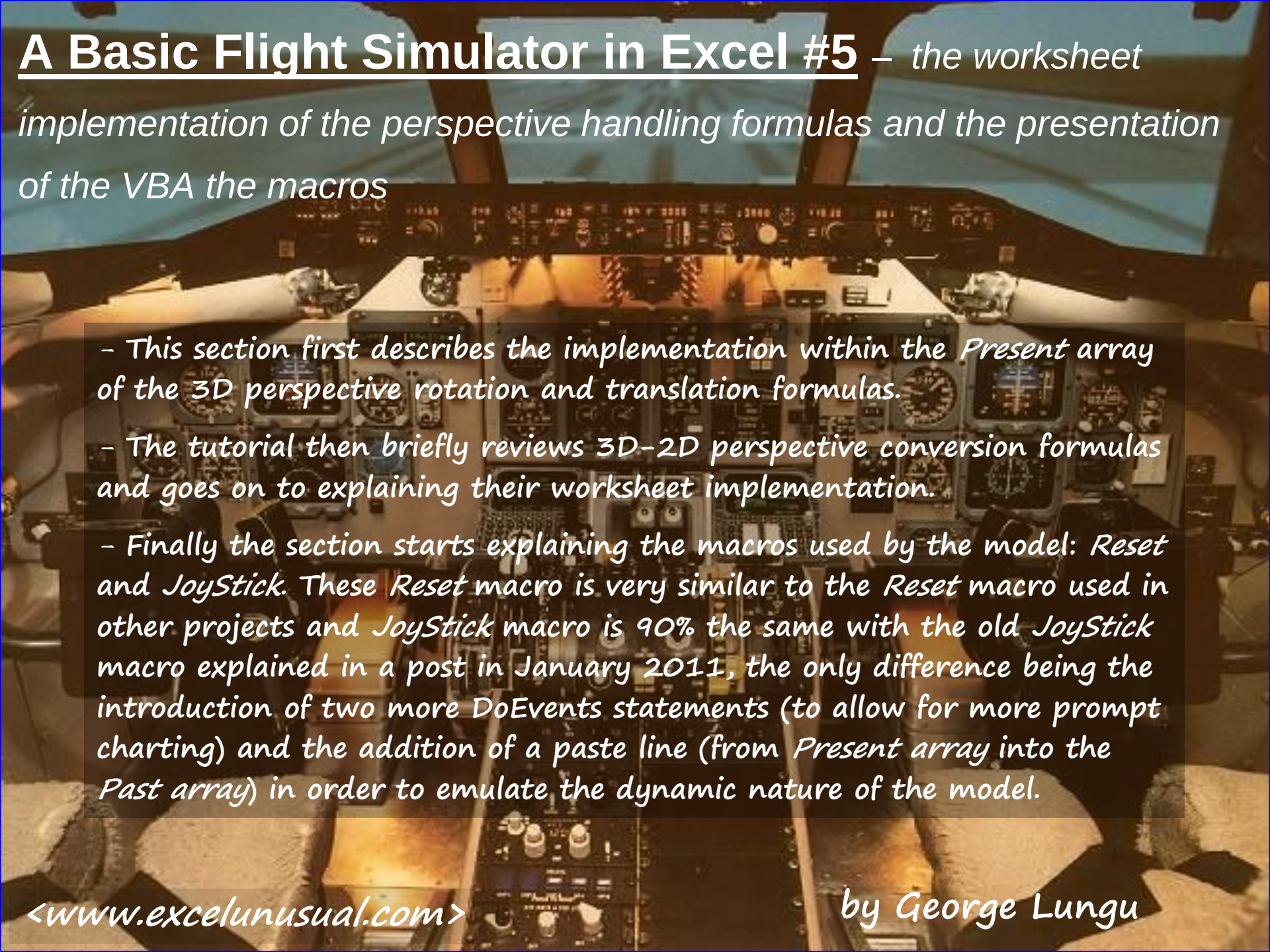
A Basic Flight Simulator in Excel #5 – *the worksheet implementation of the perspective handling formulas and the presentation of the VBA the macros*



- This section first describes the implementation within the *Present* array of the 3D perspective rotation and translation formulas.
- The tutorial then briefly reviews 3D-2D perspective conversion formulas and goes on to explaining their worksheet implementation.
- Finally the section starts explaining the macros used by the model: *Reset* and *JoyStick*. These *Reset* macro is very similar to the *Reset* macro used in other projects and *JoyStick* macro is 90% the same with the old *JoyStick* macro explained in a post in January 2011, the only difference being the introduction of two more DoEvents statements (to allow for more prompt charting) and the addition of a paste line (from *Present array* into the *Past array*) in order to emulate the dynamic nature of the model.

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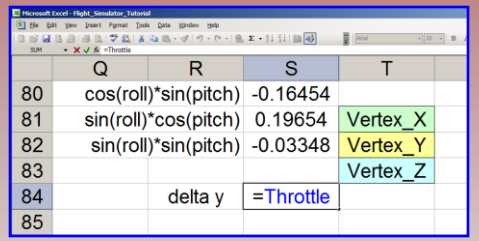
by George Lungu

Add one more entry to the input parameter area:



	Q	R	S	T
80	cos(roll)*sin(pitch)		-0.16454	
81	sin(roll)*cos(pitch)		0.19654	Vertex_X
82	sin(roll)*sin(pitch)		-0.03348	Vertex_Y
83				Vertex_Z
84		delta y	=Throttle	
85				

- Copy the "Tutorial_4" worksheet and rename the new worksheet "Tutorial_5"
- Insert a new cell label: R84: "*Delta y*", and name the range of S84, *deltaY*
- Insert the *Delta y* formula: S84: "=Throttle"
- We insert this separately as a variable since we might later want to easily increase the complexity of this formula without touching the *Present array* matrix (which is more complicated to change).

Fill out the Present (Current) array with perspective formulas (2 rotations + 1 translation):

We derived the formulas for the landscape perspective transformation before:

$$\begin{pmatrix} x_{current} \\ y_{current} \\ z_{current} \end{pmatrix} = \begin{pmatrix} 0 \\ -\Delta y \\ 0 \end{pmatrix} + \begin{pmatrix} \cos(\Delta\alpha_{roll}) & \sin(\Delta\alpha_{roll})\cdot\sin(\Delta\alpha_{pitch}) & -\sin(\Delta\alpha_{roll})\cdot\cos(\Delta\alpha_{pitch}) \\ 0 & \cos(\Delta\alpha_{pitch}) & \sin(\Delta\alpha_{pitch}) \\ \sin(\Delta\alpha_{roll}) & -\cos(\Delta\alpha_{roll})\cdot\sin(\Delta\alpha_{pitch}) & \cos(\Delta\alpha_{roll})\cdot\cos(\Delta\alpha_{pitch}) \end{pmatrix} \cdot \begin{pmatrix} x_{previous} \\ y_{previous} \\ z_{previous} \end{pmatrix}$$

Use the above formulas, the named ranges and the Past array data to fill out the Present array:

=> V271: "=cosR*V401+sinRsinP*V402-sinRcosP*V403"

=> V272: "=cosP*V402+sinP*V403-Throttle"

=> V273: "=sinR*V401-cosRsinP*V402+cosRcosP*V403"

=> Copy range V271:V273 down into range V274:V393

=> Copy range V271:V393 to the right into to the range W271:BT393 and you have just completed the Present array

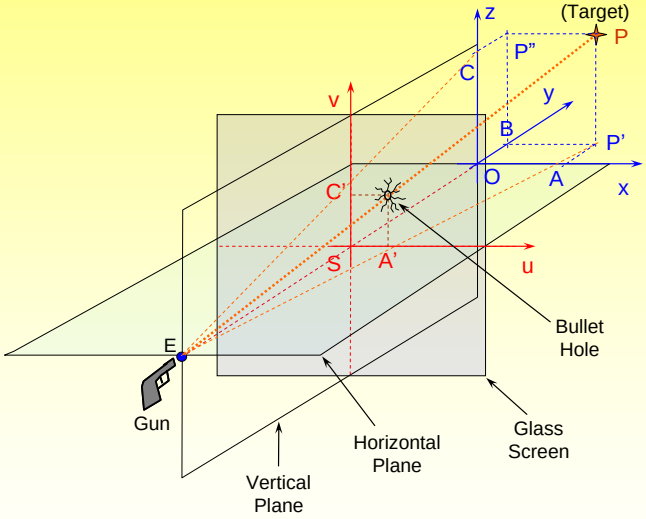
Brief review of the 3D-2D perspective conversion:

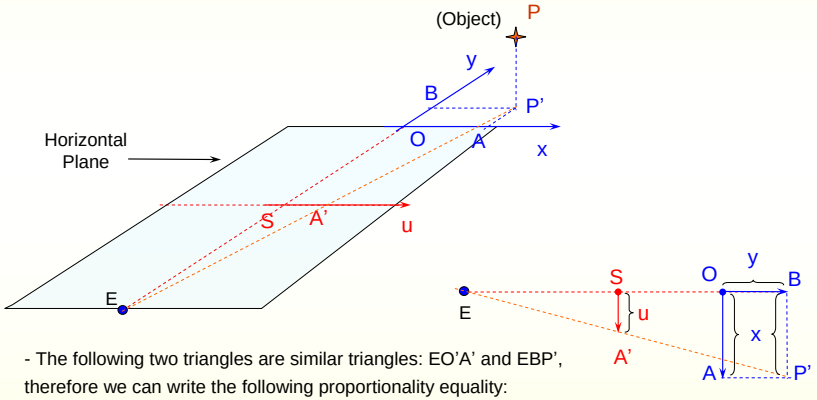
-We derived the formulas for the landscape perspective transformation in a previous post. A very brief knowledge refresh is given here.

- The "Target" point is situated in a 3D space past the glass screen (monitor surface) and it has the coordinates (x, y, z). The eye of the observer is situated in point E.

- In a descriptive way, finding (u, v) screen image coordinates after the 3D-2D perspective transformation is like shooting with an imaginary handgun from the eye to the "target" point and measuring the u-v coordinate of the bullet hole in the screen.

- Using right triangle similarity we can derive the following formulas (the derivation was done before and it's not given here:





- The following two triangles are similar triangles: EO'A' and EBP', therefore we can write the following proportionality equality:

$$\frac{ES}{EB}=\frac{SA'}{BP'}$$ And from here we can calculate "u": $$u=\frac{x\cdot ES}{ES+SO+y}$$

$$u=\frac{x\cdot ES}{ES+SO+y}$$

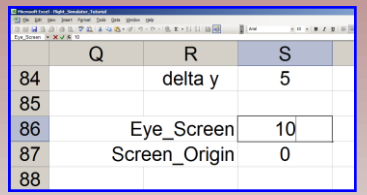
$$v=\frac{z\cdot ES}{ES+SO+y}$$

Where:

- ***ES*** is the distance between eye and screen
- ***SO*** is the distance between the screen and the origin of the object system of coordinates

The object has to be in front of the observer therefore EB (ES+SO+y>0) must be positive at all times to prevent artifacts from being displayed on the screen. While displaying multipoint shapes, the perspective conversion formulas have to be written as to *eliminate any shape* that has even one vertex which does not satisfy the previous condition, otherwise annoying artifacts have been noticed in the image.

Add two more entries to the input parameter area:



	Q	R	S
84		delta y	5
85			
86		Eye_Screen	10
87		Screen_Origin	0
88			

- Insert a new cell label: R86: "*Eye_Screen*", and name the range of S86, *Eye_Screen*
- Insert a new cell label: R87: "*Screen_Origin*", and name the range of S87, "*Screen_Origin*"
- Assign the constant 10 to the *Eye_Screen* constant and 0 to the *Screen_Origin* constant

(you can play with those constants later and choose a pair based on your visual preference).

Fill out the u-v array with 3D-2D perspective conversion formulas:

$$u = \frac{x \cdot ES}{ES + SO + y}$$

$$v = \frac{z \cdot ES}{ES + SO + y}$$

- It is very useful to make this array the same size as the Present and Past arrays.

- The u-v array will contain stacked information as follows:

=> the to top row will contain u formulas

=> the second top row will contain v formulas

=> the third top row will contain a condition later to be used to determine which triangles have a vertex behind the observers so we can "hide" or mask them in order to avoid visual artifacts

=>the rows below will have the same vertically stacked structure with periodicity of three

-Use the formulas to the right, the named ranges and the Past array data to fill out the u-v array

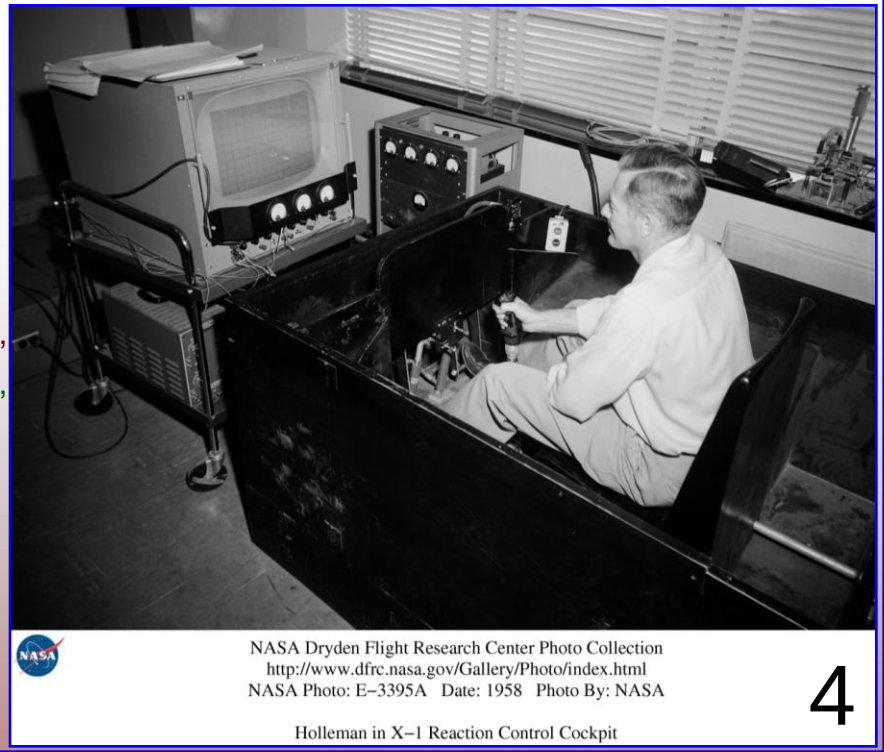
>V531: "=V401*Eye_Screen/(Eye_Screen+Screen_Origin+V402)"

>V532: "=V403*Eye_Screen/(Eye_Screen+Screen_Origin+V402)"

>V533: "=IF(Eye_Screen+Screen_Origin+V402>0,1,0)"

>Copy range V531:V533 down into range V534:V653

>Copy range V534:V653 to the right into to the range W531:BT653 and the u-v array is complete



NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/Gallery/Photo/index.html
NASA Photo: E-3395A Date: 1958 Photo By: NASA

Holleman in X-1 Reaction Control Cockpit

Retrieving the index number (showing simulation progress):

- We would like to monitor in real time how our simulation progresses, which means visualizing the number of times the macro went through the 3D-2D perspective calculation loop. In our case, since we chose the time step to be 1 second, the index would be equal to the number of seconds passed since the start of the model.
- While we could just add a line in the Joystick macro which prints the iteration number in a cell we prefer not to do that since it takes simulation time, instead take advantage of the one-operation cut and paste which will be implemented anyway to make the scene rotate and translate.
- We already have two matrices, the *Past* and *Present* between which data is exchanged (the functions in Present array take argument from the *Past array* and the results of the *Present array* are stored in the *Past array* during the next time step).
- The paste operation is done over 3 x 51 x 41 points of data out of which 3 x 41 x 41 are landscape. We could use the rest of space for the index number simulation, additional landscape and control panel instruments.

How is this implemented in the worksheet? *-> In both the Present and the Past array introduce a section for index. The present index will be a formula ($index_{current} = index_{past} + 1$) and the past index will be a constant integer number reset to 0 at the start of the takeoff.*

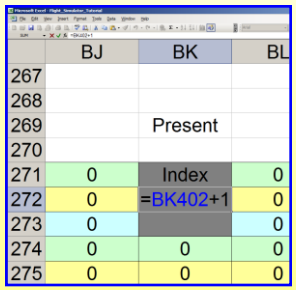
-The same macro running the joystick function will paste the results of the present array calculations in the past array and do this each cycle of the Do loop. In consequence the index will increase as the simulation progresses and this is because the arguments in the present array function are taken from the past.

- Since we have plenty of room unused we can add a title for identification both areas where the index is calculated, and we can change the background color for easy identification:

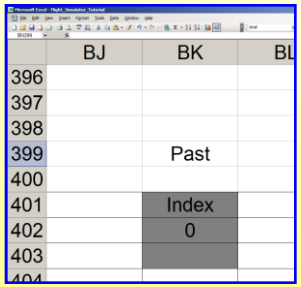
=> Insert a label in each of Present and Past matrices: BK271: “Index”, BK401: “Index”

=> BK272: “=BK402+1”

=> BK402: “=0”



	BJ	BK	BL
267			
268			
269		Present	
270			
271	0	Index	0
272	0	=BK402+1	0
273	0		0
274	0	0	0
275	0	0	0



	BJ	BK	BL
396			
397			
398			
399		Past	
400			
401		Index	
402		0	
403			

The Reset macro :

- The reset macro pastes the landscape result data from the *Present* in the *Past array* so that the data can be used by the *Present array* to calculate the perspective image during the first time step.
- The index value in the *Past array* is reset to zero.

```
Sub Reset()
[V401:BJ523] = [V81:BJ203].Value
[BK402] = 0
End Sub
```

The JoyStick macro :

- The code for this macro has to be placed in a module otherwise it won't work (the feature retrieving the mouse coordinate will not work in any sheet section of the VBA project)
- In this section of the tutorial only the API declaration and PointAPI structure will be presented below. The presentation of the JoyStick macro, which is 90% similar to the old joystick macro will be continued in the next section.
- **This part of the VBA code like all declarations has to be placed on the top of the page!!!**

```
Public Declare Function GetCursorPos Lib "user32" _
(Some_String As POINTAPI) As Long

Type POINTAPI
   X  As Long
   Y  As Long
End Type

Dim RunPause As Boolean
```

Declaration of a special API (Application Programming Interface) function which retrieves the cursor position

declaration of a special structure (Point API) used as the output type of the previous API function. It is essentially the pair of coordinates (as long integers) of the cursor on the screen started to be measured from the upper left corner of the screen.

declaration of a Boolean variable which has the role of a "switch", keeping track if the macro is running or is stopped. This will allow the macro to be started or paused by clicking the same object (the joystick chart).