SESA2024 Astronautics

University of Southampton

Chapter 5: Mission Analysis

Lecture 12 – Hohmann transfer visualisation activity

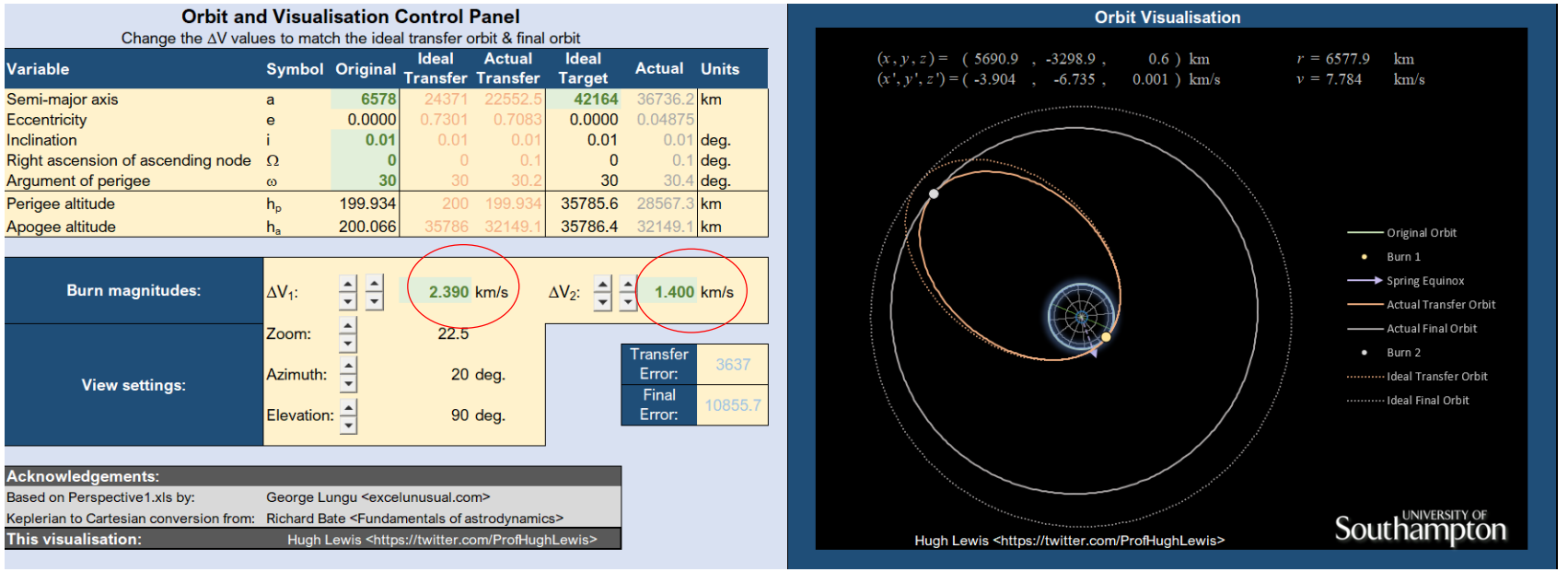
Professor Hugh Lewis

Overview of lecture 12

- This lecture describes an activity you can undertake using the “Hohmann Transfer” version of the orbit visualisation tool to support your understanding of orbital transfers, in particular the Hohmann transfer:
  - This version of the orbit visualisation tool is available to download from the Blackboard site (in the same folder as these lecture slides)
  - The tool is a Microsoft Excel spreadsheet, which has been tested on PCs and Macs
  - You may need to enable the Macros for the spreadsheet to function correctly (the underlying Visual Basic code is actually very simple; most of the “work” is done in the different worksheets)
  - The 3D rendering is actually achieved using a single 2D scatter plot (the orbital elements are converted to cartesian coordinates, which are subsequently projected onto a 2D “image” plane)

Activity

- Activity using the orbit visualisation tool:
  - Use the "Hohmann Transfer" version of the visualisation tool
    - The aim is to adjust the delta-V values for the two burns so that the actual transfer orbit matches the ideal transfer orbit, and the actual final orbit matches the ideal final orbit (with a small margin of error)
    - You can change the initial orbital elements (except the eccentricity) and the final orbit semi-major axis. In the example shown, the transfer is from a 200 km parking orbit to GEO



Orbit and Visualisation Control Panel

Change the ΔV values to match the ideal transfer orbit & final orbit

Variable	Symbol	Original	Ideal Transfer	Actual Transfer	Ideal Target	Actual	Units
Semi-major axis	a	6578	24371	22552.5	42164	36736.2	km
Eccentricity	e	0.0000	0.7301	0.7083	0.0000	0.04875	
Inclination	i	0.01	0.01	0.01	0.01	0.01	deg.
Right ascension of ascending node	Ω	0	0	0.1	0	0.1	deg.
Argument of perigee	ω	30	30	30.2	30	30.4	deg.
Perigee altitude	h_p	199.934	200	199.934	35785.6	28567.3	km
Apogee altitude	h_a	200.066	35786	32149.1	35786.4	32149.1	km

Burn magnitudes:	ΔV_1:	2.390 km/s	ΔV_2:	1.400 km/s
View settings:	Zoom:	22.5		
	Azimuth:	20 deg.		
	Elevation:	90 deg.		

Transfer Error:	3637
Final Error:	10855.7

Acknowledgements:	
Based on Perspective1.xls by:	George Lungu <excelunusual.com>
Keplerian to Cartesian conversion from:	Richard Bate <Fundamentals of astrodynamics>
This visualisation:	Hugh Lewis <https://twitter.com/ProfHughLewis>

Activity

- Activity using the orbit visualisation tool:
  - Use the "Hohmann Transfer" version of the visualisation tool

Orbit and Visualisation Control Panel

Change the ΔV values to match the ideal transfer orbit & final orbit

Variable	Symbol	Original	Ideal Transfer	Actual Transfer	Ideal Target	Actual	Units
Semi-major axis	a	6578	24371	22552.5	42164	36736.2	km
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Inclination	i	0.01	0.01	0.01	0.01	0.01	deg.
Right ascension of ascending node	Ω	0	0	0.1	0	0.1	deg.
Argument of perigee	ω	30	30	30.2	30	30.4	deg.
Perigee altitude	h_p	199.934	200	199.934	35785.6	28567.3	km
Apogee altitude	h_a	200.066	35786	32149.1	35786.4	32149.1	km

Burn magnitudes:	ΔV_1:	2.390 km/s	ΔV_2:	1.400 km/s	
View settings:	Zoom:	22.5	Transfer Error:	3637	
	Azimuth:	20 deg.	Final Error:	10855.7	
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This part of the control panel displays the orbital elements:

- The original/parking orbit
- The ideal transfer orbit (computed using the energy equation)
- The actual transfer orbit (computed using the semi-major axes of the original orbit and the value of ΔV_1)
- The ideal/target orbit
- The actual final orbit (computed using the value of ΔV_2)

You can change the values in green (in this section only) by typing into the cells

Activity

- Activity using the orbit visualisation tool:
  - Use the "Hohmann Transfer" version of the visualisation tool

Orbit and Visualisation Control Panel

Change the ΔV values to match the ideal transfer orbit & final orbit

Variable	Symbol	Original	Ideal Transfer	Actual Transfer	Ideal Target	Actual	Units
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Inclination	i	0.01	0.01	0.01	0.01	0.01	deg.
Right ascension of ascending node	Ω	0	0	0.1	0	0.1	deg.
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Burn magnitudes:	ΔV_1:	2.390 km/s	ΔV_2:	1.400 km/s	
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Note that it *is* possible to change the eccentricity of the original and ideal target orbits, but you are advised not to do so

- The Hohmann transfer is used to manoeuvre between two *circular* orbits

It is also possible to enter inclination or right ascension values for the original orbit that are different from those of the final orbit, but you are advised not to do so

- The Hohmann transfer is used to manoeuvre between two *coplanar* orbits

Activity

- Activity using the orbit visualisation tool:
  - Use the "Hohmann Transfer" version of the visualisation tool

Orbit and Visualisation Control Panel

Change the ΔV values to match the ideal transfer orbit & final orbit

Variable	Symbol	Original	Ideal Transfer	Actual Transfer	Ideal Target	Actual	Units
Semi-major axis	a	6578	24371	22552.5	42164	36736.2	km
Eccentricity	e	0.0000	0.7301	0.7083	0.0000	0.04875	
Inclination	i	0.01	0.01	0.01	0.01	0.01	deg.
Right ascension of ascending node	Ω	0	0	0.1	0	0.1	deg.
Argument of perigee	ω	30	30	30.2	30	30.4	deg.
Perigee altitude	h_p	199.934	200	199.934	35785.6	28567.3	km
Apogee altitude	h_a	200.066	35786	32149.1	35786.4	32149.1	km

Burn magnitudes:	ΔV_1:	2.390 km/s	ΔV_2:	1.400 km/s	
View settings:	Zoom:	22.5	Transfer Error:	3637	
	Azimuth:	20 deg.	Final Error:	10855.7	
	Elevation:	90 deg.			

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This part of the control panel displays the delta-V values for the two-impulse Hohmann transfer:

- The value of ΔV_1 for the first burn
- The value of ΔV_2 for the second burn

You can change the values in green (in this section only) by clicking on the arrows to increase of decrease the delta-V

- The buttons on the left increment/decrement the delta-V values by 0.01 km/s (click and hold for rapid change)
- The buttons on the right increment/decrement the delta-V values by 0.001 km/s

Activity

- Activity using the orbit visualisation tool:
  - Use the "Hohmann Transfer" version of the visualisation tool

Orbit and Visualisation Control Panel

Change the ΔV values to match the ideal transfer orbit & final orbit

Variable	Symbol	Original	Ideal Transfer	Actual Transfer	Ideal Target	Actual	Units
Semi-major axis	a	6578	24371	22552.5	42164	36736.2	km
Eccentricity	e	0.0000	0.7301	0.7083	0.0000	0.04875	
Inclination	i	0.01	0.01	0.01	0.01	0.01	deg.
Right ascension of ascending node	Ω	0	0	0.1	0	0.1	deg.
Argument of perigee	ω	30	30	30.2	30	30.4	deg.
Perigee altitude	h_p	199.934	200	199.934	35785.6	28567.3	km
Apogee altitude	h_a	200.066	35786	32149.1	35786.4	32149.1	km

Burn magnitudes:	ΔV_1:	2.390 km/s	ΔV_2:	1.400 km/s	
View settings:	Zoom:	22.5			
	Azimuth:	20 deg.			
	Elevation:	90 deg.			

Transfer Error:	3637
Final Error:	10855.7

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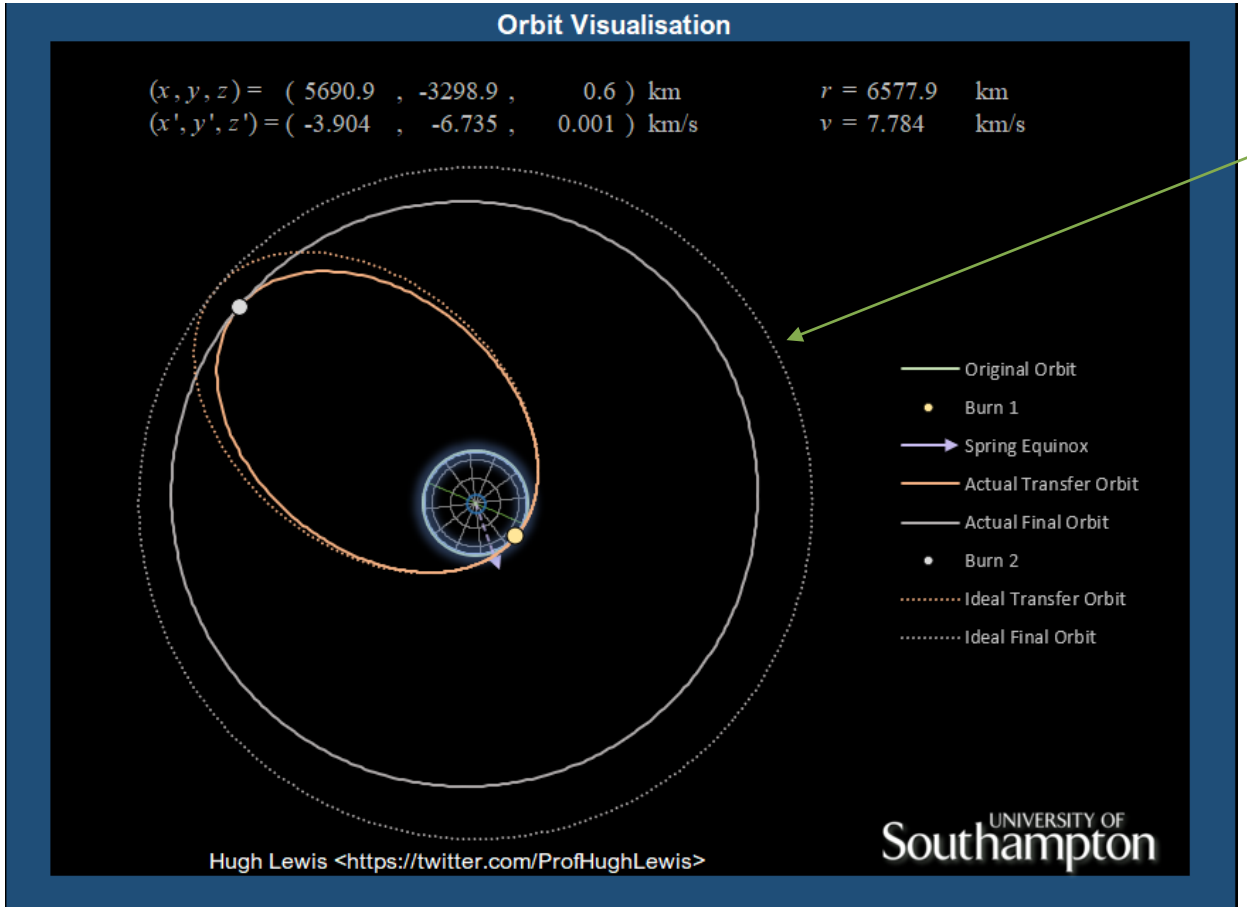
This part of the control panel displays the error between the actual orbits and the target/ideal orbits:

- The value is just the sum of the difference in the perigee altitudes and the apogee altitudes
- You can use these error values to help you to match the actual orbits to the target orbits

Activity

- Activity using the orbit visualisation tool:
  - Use the "Hohmann Transfer" version of the visualisation tool

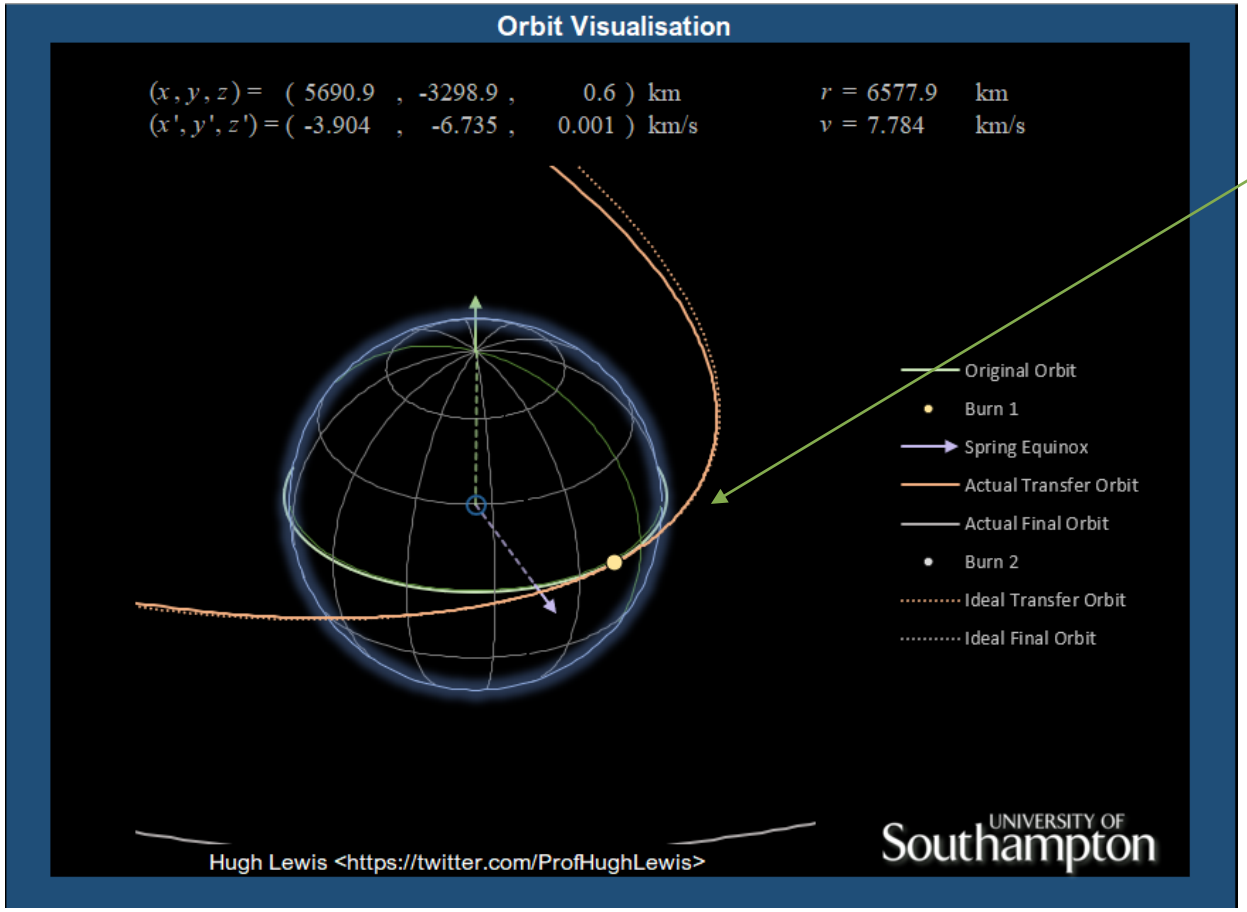


The dashed lines in the orbit visualisation are used to show the target/ideal transfer orbit and the target/ideal final orbit

- By adjusting the delta-V values you can see how the actual orbits change
- You can use this display to help you to match the actual orbits to the target orbits and, hence, find the delta-V values for the two burns

Activity

- Activity using the orbit visualisation tool:
  - Use the "Hohmann Transfer" version of the visualisation tool



You can use the zoom setting to take a closer look at the initial orbit and the first burn (which, in this example, takes place close to the Earth)

- The position of the first burn is shown using a yellow marker
- The position of the second burn is shown using a grey marker

Activity

- Activity using the orbit visualisation tool:
  - Use the "Hohmann Transfer" version of the visualisation tool

Orbit and Visualisation Control Panel

Change the ΔV values to match the ideal transfer orbit & final orbit

Variable	Symbol	Original	Ideal Transfer	Actual Transfer	Ideal Target	Actual	Units
Semi-major axis	a	6578	24371	22045.4	42164	35796.3	km
Eccentricity	e	0.0000	0.7301	0.7016	0.0000	0.04795	
Inclination	i	0.01	0.01	0.01	0.01	0.01	deg.
Right ascension of ascending node	Ω	0	0	0.1	0	0.1	deg.
Argument of perigee	ω	30	30	30.2	30	30.4	deg.
Perigee altitude	h_p	199.934	200	199.934	35785.6	27701.8	km
Apogee altitude	h_a	200.066	35786	31134.8	35786.4	31134.8	km

Burn magnitudes:	ΔV_1:	2.370 km/s	ΔV_2:	1.400 km/s
View settings:	Zoom:	22.5		
	Azimuth:	20 deg.		
	Elevation:	90 deg.		

Transfer Error:	4651.26
Final Error:	12735.4

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Orbit and Visualisation | --Hohmann Transfer Calcs-- | ||----------||

The Hohmann transfer calculations can be found in the "—Hohmann Transfer Calcs—" worksheet: