## Introduction to Aerospace Engineering

Lecture slides



## Intro to Aerospace Engineering AE1101ab Special vehicles/future

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# Principles of flight?

Three ways to fly...

**T**UDelft





## Overview of aircraft types

- Ways to fly
  - Being lighter than air
    - Balloons 1
    - Airships 🗸
  - Pushing air downwards
    - Airplanes V
    - Ground effect planes
    - Helicopters
    - Other VTOL/STOVL
  - Pushing something else downwards
    - Rockets
    - Jet pack???
- Future aircraft
  - Future UAVs
  - Personal Air Vehicles
  - Hypersonic planes
  - Micro Aerial Vehicles
  - Clean era aircraft/'Green aircraft'



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# 1.

# Ground effect aircraft



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## Ground effect aircraft use "cushion of air"



 Hovercraft is not ground effect aircraft, but also uses cushion of air



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## What is the "ground effect"?





- No vertical speed at ground level
- As if mirrored aircraft generates lift with its inverted downwash
- Increase in lift can be up to 40%!



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## What is the "ground effect"?



 Reduction of induced drag: 10% at half the wingspan above the ground

**T**UDelft

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# Is it a boat? Is it a plane? No, it's the Caspian Sea Monster!

Lun-class KM Ekranoplan

Operator: Russian navy In service: 1987-1996? Nr built: 1 (MD-160) Length: 100 m Wing span: 44 m Speed: 297 kts (550 km/h) Range: 1000 nm (1852 km) Empty weight: 286,000 kg Max TOW: 550,000 kg Thrust: 8 x 127,4 kN Crew: 6 Armament:

- 6 missile launchers for ASW
- 23 mm twin AA-gun



 Russian KM-Ekranoplan a.k.a.
"The Caspian Sea Monster" Built in 1966



**Serious video** 



**Cool video** 



# A-90 Orlyonok: Troops transport (5 ex.)





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## Current fate of these vehicles

## • You can still find them on Google Earth! Check ports of Caspian Sea.





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## Future for ground effect aircraft?





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## Future for ground effect aircraft?







## Future for ground effect aircraft? GEV = Ground Effect Vehicle





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## Future for ground effect aircraft?





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# 2.

## Helicopters



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# Helicopters

Remember, a helicopter is nothing more than a large collection of parts flying in close formation, held together with grease and copper wire

### Helicopters are:

- Creating more noise (internal & external)
- Less fuel efficient
- Less environmentally friendly
- More expensive to buy & operate
- Less comfortable for passengers
- Harder to fly

## But can:

- Land & take-off anywhere
- Hover











## Helicopters in service since 1940s

**VS-300** 



Igor Sikorsky (1889 - 1972) builds first helicopter in 1909 but it was more than 25 years before early practical machines - like the VS-300 (pictured) were flown in prewar trials.



Sikorsky R-4 Hoverfly 1944





Bolkow BO-105C



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## Horizontal flight



(a) equilibrium of forces



(a) main rotor power in level flight



## Helicopter flight control

An oft-quoted analogy is that flying an airplane is like riding a bicycle, but hovering a helicopter is like riding a unicycle.



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## Helicopters are hard to fly



The story: Man buys helicopter. Man needs lessons. Man wants to try. Now.



## Helicopter control: swash plate



Invented by Boris Yuryev in 1910 Russian aerodynamicist

#### Swashplate on a radio-controlled helicopter

- 1 Non-rotating outer ring (blue)
- 2 Turning inner ring (silver)
- 3 Ball joint
- 4 Control (pitch) preventing turning of outer ring
- 5 Control (roll)
- 6 Linkages (silver) to the rotor blade
- # Linkages (black) that make the inner ring turn

#### Cyclic:

- Roll & pitch control
- Tilt swash plate

#### **Collective:**

- changes angle of attack of all rotor blades
- move entire swash playe up& down



## Horizontal flight



(b) rotor blade velocity distribution





## Tail rotor compensates torque





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## So what to do when tail rotor fails?





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## So what to do when tail rotor fails?





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## Alternatives for tail rotor

#### NOTAR SYSTEM









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## McDonnell Douglas Explorer



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## Kamow Ka-50



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## Answer: Autorotation Same for an engine failure







## Dead man's region









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## V-22 Osprey: Tilt-rotor aircraft







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## STOVL/VTOL



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### BAe Sea Harrier





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**TU**Delft

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## Follow-up: McDonnel Douglas AV-8B





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## NG-Harrier: STOVL JSF F-35B

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## Rockets for lift on aircraft?



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#### Boeing B-47B, rocket assisted take off, April 15, 1954

### JATO rockets Jet Assisted Take-Off

often used during the 1940s-1960s to boost heavily-laden aircraft off the ground



## Jet pack or rocket belt

Technical characteristics of rocket pack								
	Bell Rocket Belt	RB 2000 Rocket Belt						
Duration	21 s	30 s						
Thrust	136 kgf (1.33 kN) (calculated 127 kgf or 1.25 kN)	145 kgf (1.42 kN)						
Maximum distance	approximately 250 meters							
Maximum altitude	18 m	30 m						
Maximum speed	55 km/h	96 km/h						
Equipped mass	57 kg	60 kg						
Fuel stock	19 liters	23 liters						

#### Risk of unstability:

- Check moments
- Where is thrust applied?





## Jet pack





Jet P.I. Equipment weight ~ 70 kg

Name	Max flight time	Max distance	Max speed	Max height	Max pilot weight	Fuel	Motor type	Fuel capacity	Price
Jet pack H202	33 seconds	500 ft	70 mph	120ft	180 lbs	H <sub>2</sub> O <sub>2</sub>	rocket	5.8 gallons	Not for sale
Jet pack H202-Z	43 seconds	1500 ft	77 mph	250ft	180 lbs	H <sub>2</sub> O <sub>2</sub>	rocket	8 gallons	Not for sale
Jet pack T-73	@ 9 minutes	@ c. 11 miles	@ 83 mph	@ 250ft	180 lbs.	Jet-A fuel	T-73 jet motor	5 gallons	\$200,000 incl. training

A Jet Pack H202 was flown for 34 seconds in Central Park on the 9 April 2007 episode of the Today Show, and sold for \$150,000. But http://www.jetpackinternational.com/equip.html 🗗 says (as at 1 January 2009) that their H202 jetpacks are for demonstration only, not for sale.



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## Future aircraft: Unmanned Aerial Vehicle (UAV)



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## UAVs



- Original goal: One man controlling multiple aircraft
- Current situation: 4 man controlling one UAV
- UAVs crash 100 times more often than controlled a/c
- Situation is improving by using more automation
- Strictly speaking: an R/C toy airplane is a UAV
- But UAVs are no toys









- Surveillance UAV
- Records:
  - altitude 65,380 ft March 21, 2001
  - Endurance 30 hr 24 min 1 March 21, 2001
  - First UAV crossing pacific: 8214 nm in 22 hours April 24, 2001



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## Global Hawk is not a toy



### Future: UCAV?





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## Remaining issues

- Reliability, responsibility
- Less controllers per vehicle
- Acceptance:
  - In civil airspace
  - For civil operations: cargo?

Passengers?



"Ladies & gentlemen, this aircraft is completely controlled by robots. So nothing can go wrong, nothing can go wrong, nothing can go wrong, nothing can go wrong, nothing...."





## Future aircraft: Personal Air Vehicle (PAV)



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### Henry Ford (July 30, 1863 – April 7, 1947)

"Mark my word – a combination of airplane and motor car is coming. You may smile, but it will come."





## Steps 1 and 2 are a reality. Step 3 is in progress!





## Mass production: price equals car...

## Which one would you choose?



- Speed: 120 km/h
- Mileage: 1 op 8,5 km
- 5 persons
- Only drive
- Plenty of space

- Speed: 500 km/h
- Mileage: 1 op 8,5 km
- 4 persons
- Vertical take-off
- Flying no traffic jam



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## Dutch initiative: PAL-V



Gyrocopter and motorcyle hybrid

By designer of Carver

Proven concept:





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#### Hybrids: Who solves it will be rich....







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## Hypersonic planes



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### Hypersonic plane to reach Australia in under 5 hours & eco friendly(?)

- ESA funded project: A-2
- Current problem: How to capture NO<sub>x</sub> output (Air burns at high temperatures, creating NO<sub>x</sub>)
- Astrox: in two hours to other side of the world





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## MAV: Micro Aerial Vehicle



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## Delfly & Delfly nano



• Check out our MAVlab



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## Future aircraft: Green Aircraft



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## Why Cleanera is necessary.



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## Energy transitions





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## Growth is our only real problem...



Clean Era

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### Em. professor Bartlett, Colorado University, Boulder



Topics addressed:

- population growth
- energy consumption
- how it all will end

Eternal & exponential growth is impossible

Situation is more urgent than you Will intuitively think it is.

#### http://www.youtube.com/watch?v=F-QA2rkpBSY

Clean Era

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## Other youtube tip: Home by Yann Arthus-Bertrand



Entire movie, made in 2008, on Youtube in HD with Eng subtitles: <u>http://www.youtube.com/watch?v=jqxENMKaeCU</u>



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## The Green Aircraft





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## Ambition: *Flying Nuna/Formula Zero* Demonstrator of technologies











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## The future?



Future clean energy sources:

- Nuclear fusion
- Photovoltaic
- Wind energy....

