Green Air Transport Technologies

Masterclass Ministerie I&M

Prof.dr.ir. Jacco Hoekstra

Menselijk aandeel aan “grote natuur”?

Maar of dat **CO2** uitstoot was en hoeveel het **aandeel menselijke** in de normaal aanwezige klimaat verandering is. En dan aangetoond met metingen uit de laatste 100 jaar.Want vaststaand is dat maar ca 0,4% van de lucht **CO2** is en daarvan ruim 90% natuurlijk en niet menselijk oorsprong

ockhams-scheermes · 03/11/2018
Replying to @JE_THIJSE and @EricJorem

Aanzienlijk **aandeel**? Van alle **CO2** is de **menselijke** bijdrage 3,2% Dat is bijna niets eigenlijk en al zeker niet genoeg om te zeggen dat het de knop is om het klimaat te regelen.

1

Raf Konings @Raphque · 29/10/2018
Replying to @Klimaatkonijn74 @WviEl and 11 others

Jawel, waarin **CO2** slechts een miniem **aandeel** heeft, en waarvan de **menselijke** component van **CO2** nog een véél miniemer **aandeel** heeft.
In échte broeikassen zorgt het and wel voor mooie oogsten...

1

Stofzuiger des Vaderl... · 23/12/2018
Replying to @EcoBalans @theowar and @wierdduk

Zure appels en peren. **CO2** maakt 0,038% van de atmosfeer uit. Menselijk **aandeel** in uitstoot is 0,0015% van totale uitstoot. **Aandeel** Nederland in wereldwijde (**menselijke**) uitstoot is 0,0044%. En daarvoor wordt de middenklasse fiscaal doodvermoord.

1

Crypto Corky @CorCry... · 22/12/2018
Replying to @D66 @HenkStrating and @RobJetten

Dat is feitelijk onjuist. U liegt. Er is consensus over opwarming. Er is GEEN consensus over: A) Hoe belangrijk het (realitief kleine) **menselijke aandeel** van **CO2** creatie is.
B) In hoeverre we weten dat de (volledig willekeurige) 2% norm van Parijs een positief gevolg zal hebben

ELSEVIER WEEKBLAD

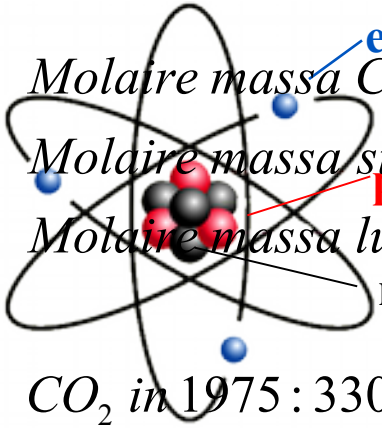
De Telegraaf

Menselijk aandeel aan “grote natuur”

Straal aarde $r = 6371\,km$

Oppervlakte $= 4\pi r^2 = 5.1 \cdot 10^{14}\,m^2$

Luchtdruk zeeniveau $p_0 = 1013.25\,mbar(hPa) \Rightarrow$ *massa atmosfeer* $5.27 \cdot 10^{18}\,kg$



Molaire massa CO_2 : $44\ g\ /\ mol\ (12+16+16)$

Molaire massa stikstof : $28\ g\ /\ mol\ (14+14)$

Molaire massa lucht : $28.97\,g\ /\ mol\ (N_2, O_2, Ar, CO_2, misc)$

78% N_2

21% O_2

1% Ar

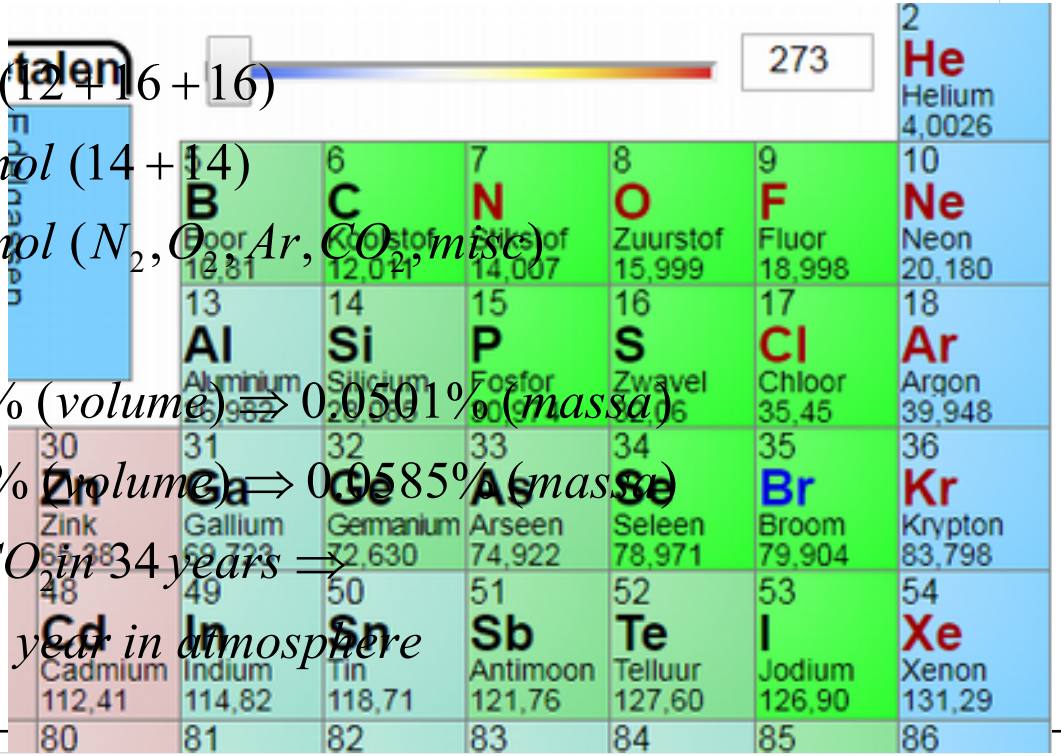
0.03 - 0.04 % CO_2

CO_2 *in* $1975 : 330\,ppm = 0.0330\%$ (*volume*) $\Rightarrow 0.0501\%$ (*massa*)

CO_2 *in* $2009 : 385\,ppm = 0.0385\%$ (*volume*) $\Rightarrow 0.0585\%$ (*massa*)

$0.0084\% = 442680$ *miljard kg* CO_2 *in* 34 *years* $\Rightarrow$

13020 *miljard kg* CO_2 *extra per year in atmosphere*



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6	7	8	9
C	N	O	F
Koolstof	Stikstof	Zuurstof	F
12,011	14,007	15,999	1
14	15	16	1

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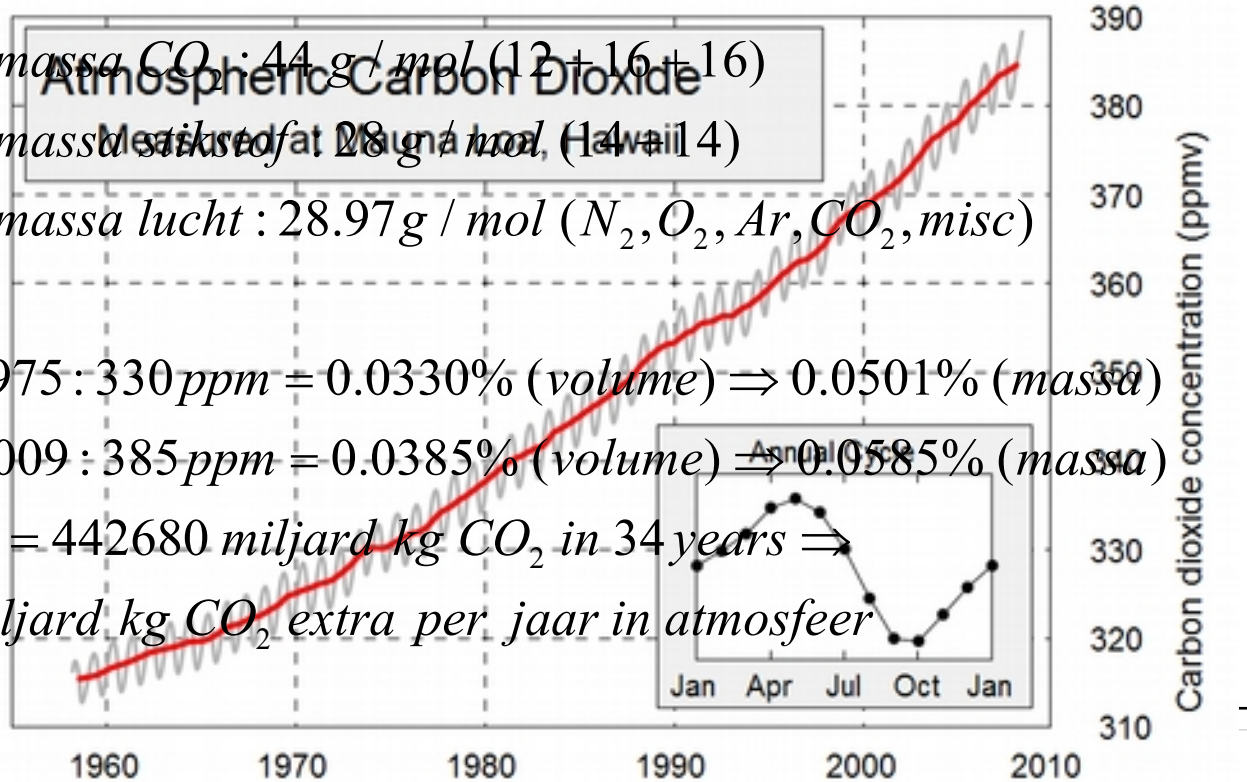

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Dagelijkse globale oliegebruik : 80 *million vaten*

$\Rightarrow$ 29220 *million vaten / jaar*

1 *vat olie resulteert in* 437 *kg* CO_2

} 12769 *miljard kg* CO_2 *per jaar door alleen olie*

olie is ongeveer 50% *van fossiele brandstoffen*

Totaal fossiele brandstoffen = 25538 *miljard kg*

$$\textit{Anthropogeen deel} : \frac{25528}{12769} = 200\ \%$$

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OLE

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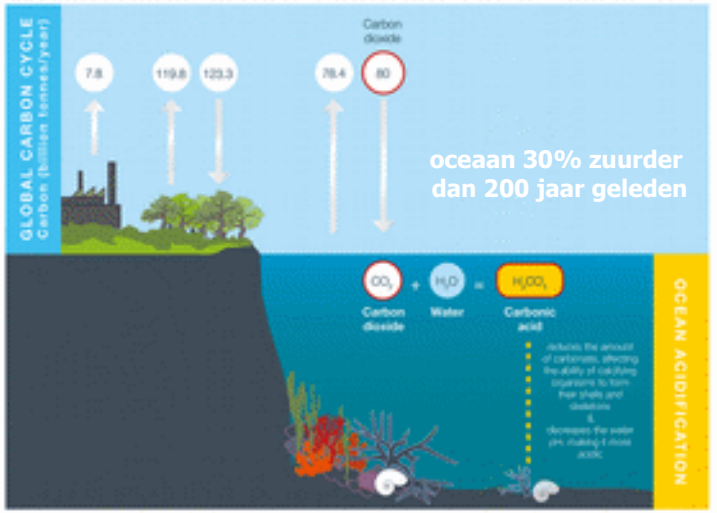
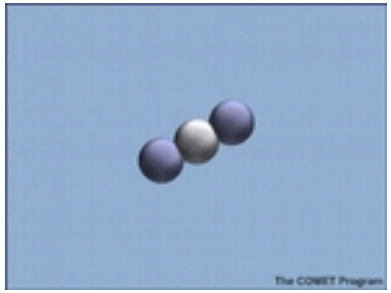


CO_2 link to global warming



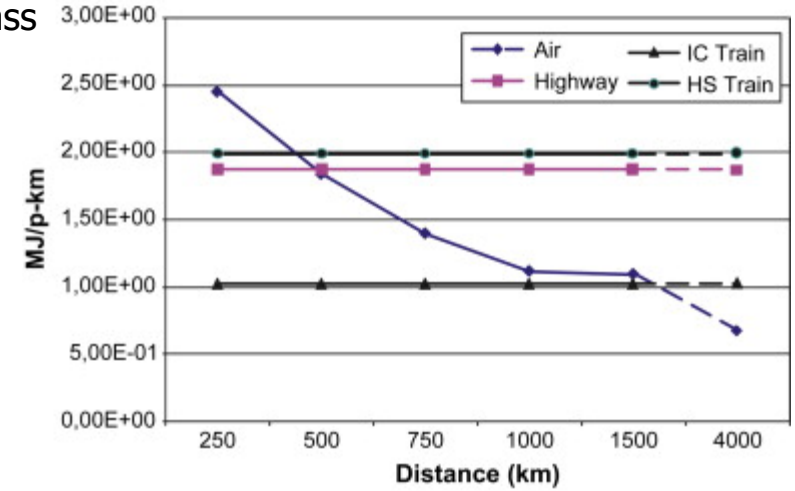
- "CO_2 is only 0.04% so a small part of atmosphere" is about as relevant as "atmosphere is only 0.00008% of mass of the earth" as it is about the effect
- Physics of warming effect CO_2 is well understood*
- Warming of past 40 years fits predicted effect as function of CO_2 *
- Predicting 40 years ahead seems reasonable confirmation *
- Atmospheric composition change unprecedented in recent history

*Bron: Diesrede Prof. dr. Pier Siebesma (Geosciences TU Delft)

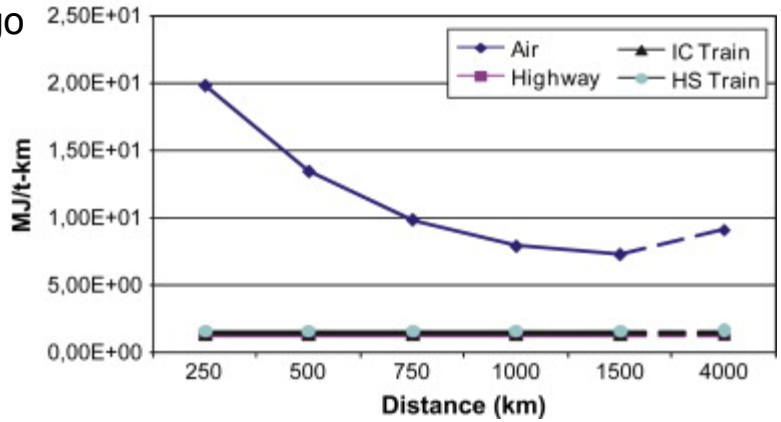
Train vs plane

Material Input

Pass



Cargo



	Fuel / Propulsion energy	Total MJ/p-km >= 4000 km
A320:	1.20 MJ/p-km	1.80 MJ/p-km
B747:	1.90 MJ/p-km	2.50 MJ/p-km
IC:	0.14 MJ/p-km	1.50 MJ/p-km
TGV:	0.50 MJ/p-km	2.50 MJ/p-km

	Fuel / Propulsion energy	Total MJ/p-km = 1000 km
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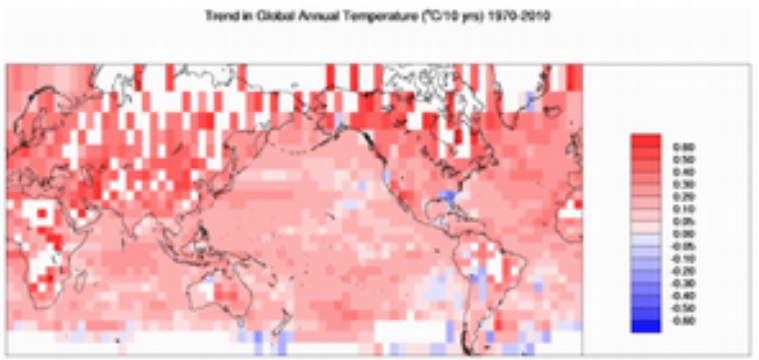
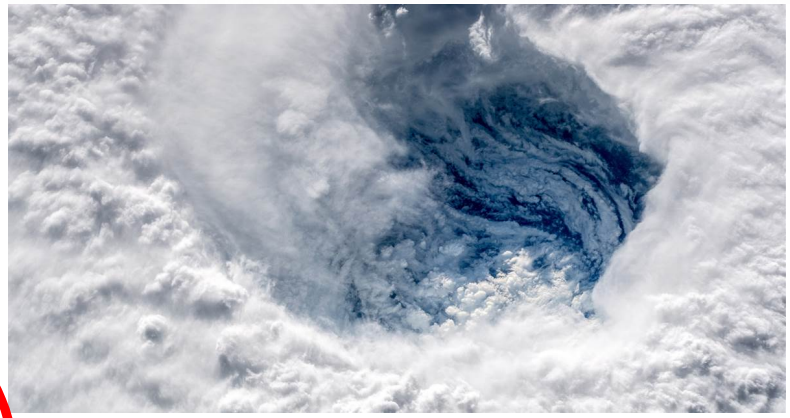
TGV:	0.50 MJ/p-km	2.50 MJ/p-km

Intercity always beats a/c
TGV beats a/c when:
- using tracks more intensively (same for runways?)
- using zero emission energy for construction tracks

- Sources:
  Mirco Federici - Air versus terrestrial transport modalities: An energy and environmental comparison
  David McKay - Sustainable Energy without the hot air

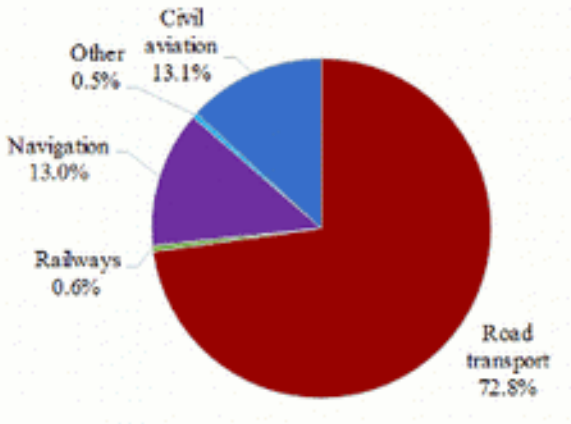
Duurzaamheid en luchtverkeer





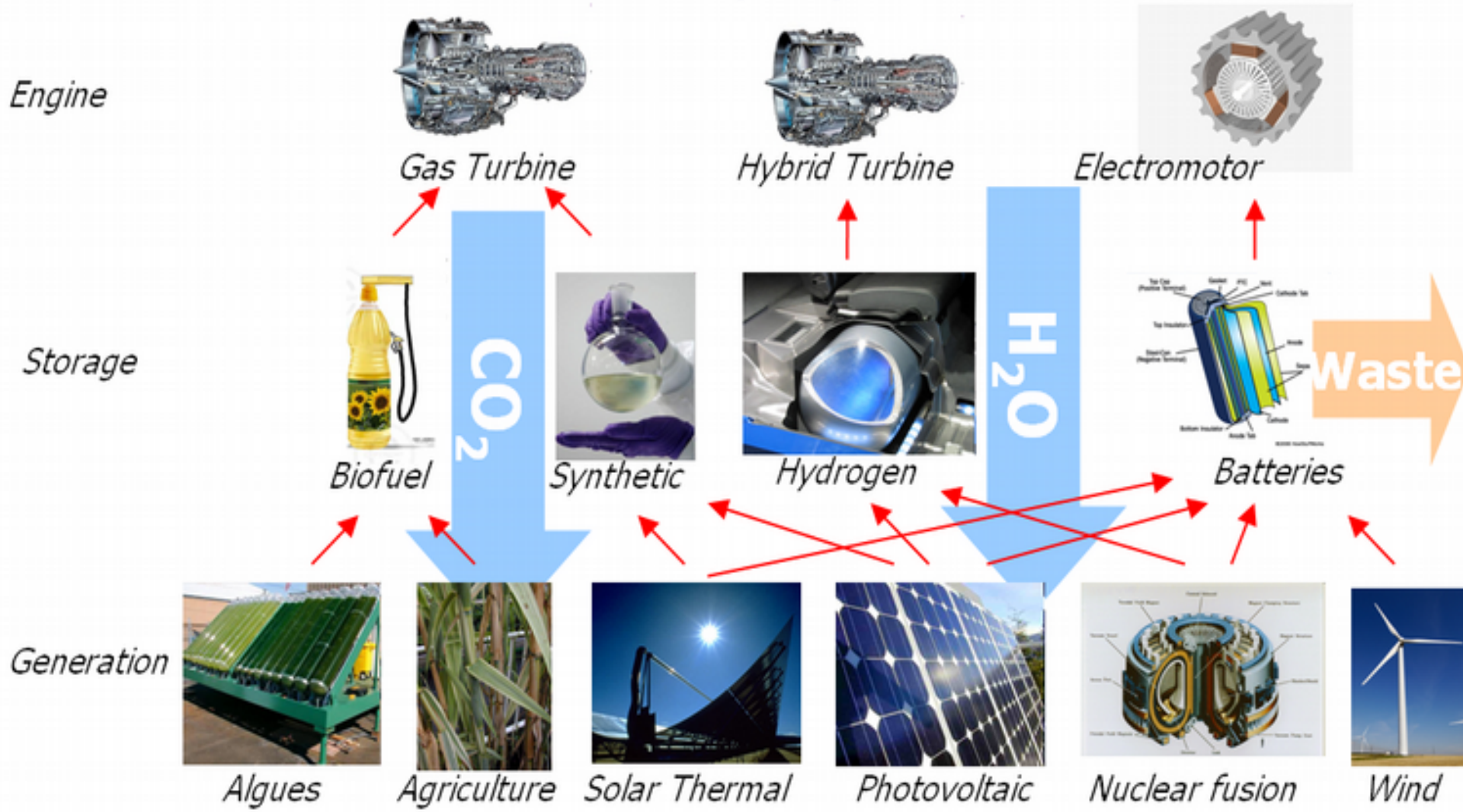
Volkskrant fact check: Een ticket naar Thailand is nog altijd vervuilender dan een jaar vlees eten.

Contribution air transport



- IATA: 2% of CO_2 by air transport (= 1992!)
- Average growth air transport: 5.2 % per year globally
- 1992-2019 = 27 years => 1.052^{27} = 3.93 x
- 2005: 3.5% (IPCC) to 5% (UK Gov) global warmth due to air transport
- CO_2 is only part of story:
  - Tropopause/Stratosphere
  - Contrails (H_2O), less well understood
- Literally everybody can claim to only contribute a minor fraction

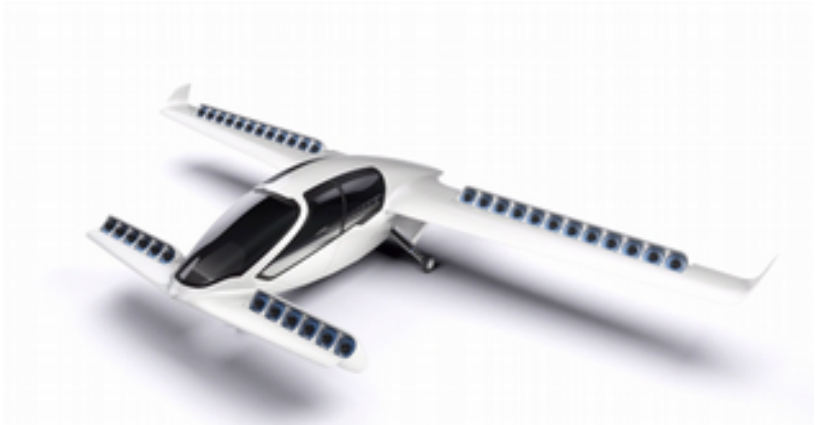
Roads to sustainable propulsion for aircraft



Electrical airplanes?

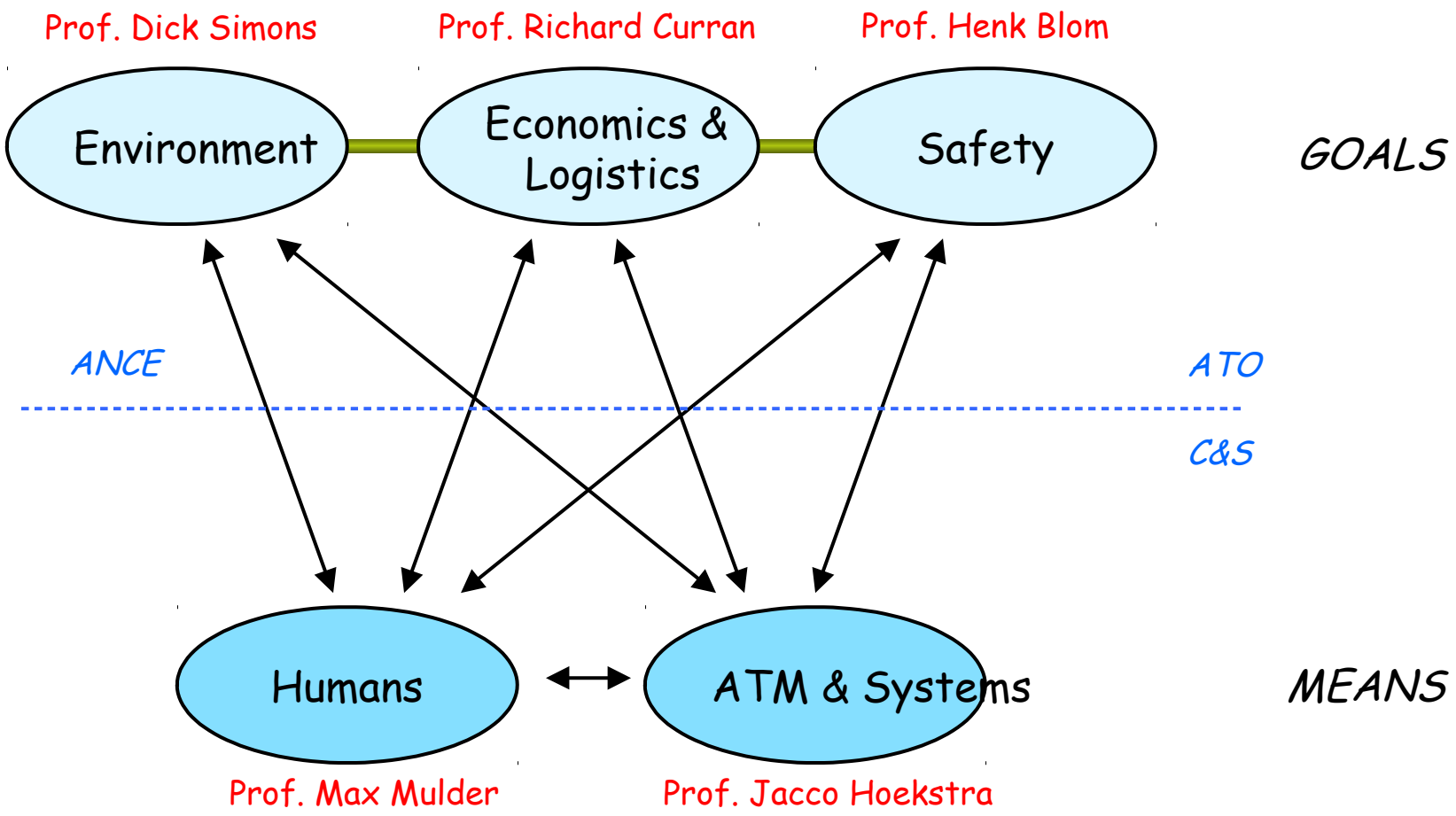
"Even considering the improvements possible …… the gas turbine could hardly be considered a feasible application to airplanes, mainly because of the difficulty with the stringent weight requirements."
Gas turbine committee, US National Academy of Sciences (1940)

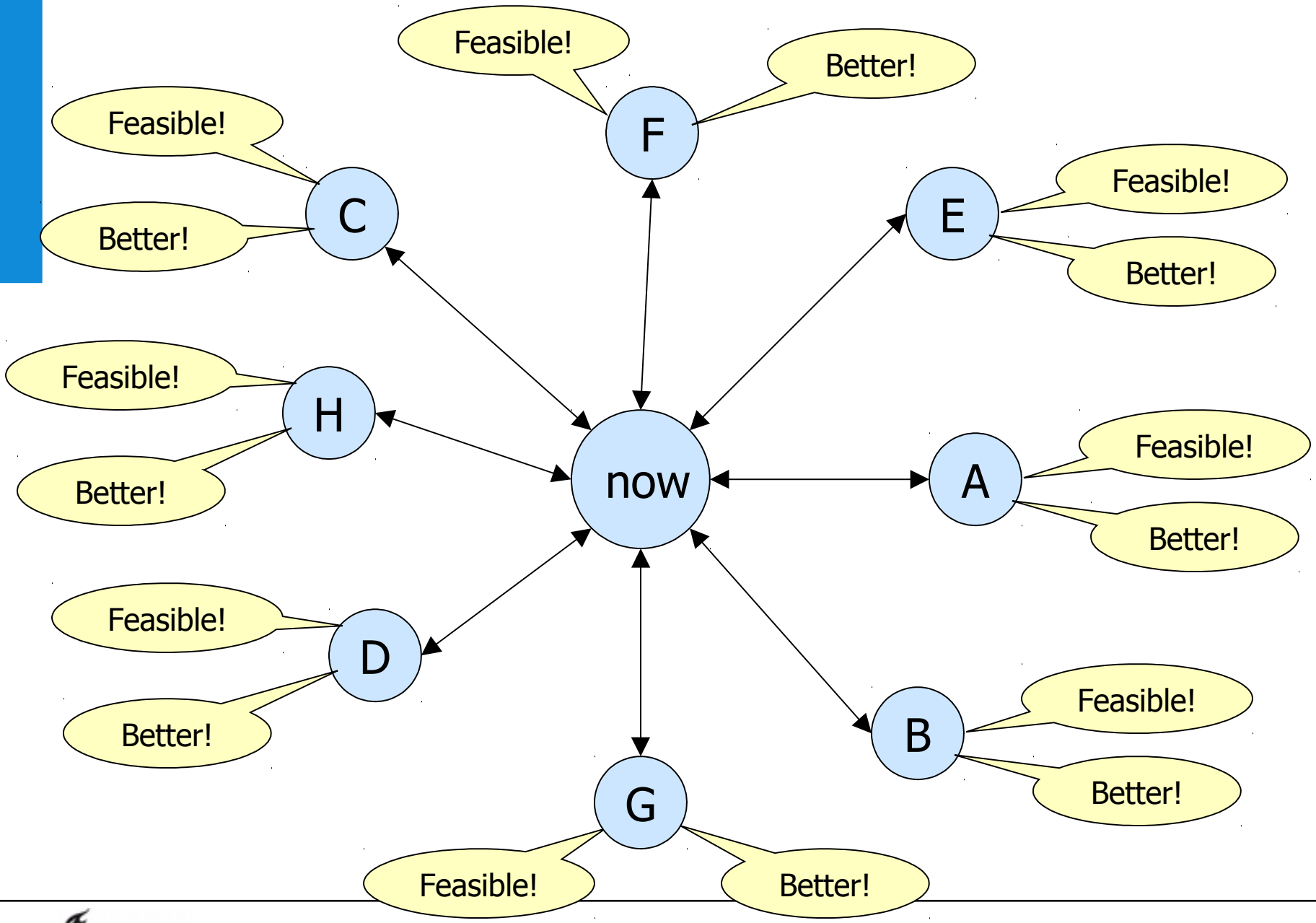
Electrical airplanes



Lilium Electrical Jet, VTOL

Alice Commuter
9 passagiers, 450 km/hr, 1100 km,


Prof. Dick Simons
Prof. Richard Curran
Prof. Henk Blom
Environment
Economics & Logistics
Safety
GOALS
ANCE
ATO
C&S
Humans
ATM & Systems
MEANS
Prof. Max Mulder
Prof. Jacco Hoekstra


Feasible!
Better!
F
Feasible!
Better!
C
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E
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H
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Better!
now
A
Feasible!
Better!
Feasible!
Better!
D
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B
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Better!
G
Feasible!
Better!

CNS/ATM Research Themes

- **Theme 1: ATM Foundation -** What is foundation of ATM?
  - *Use a.o. common open tool and scenarios to establish this*
  - *Data mining (ADS-B, radar data, Ectl PRC, etc.) and study traffic flow dynamics*

- **Theme 2: Surveillance -** How to exploit benefits of ASAS/ADS-B?
  - *Concept & System prototypes development & validation*
  - *Improved Trajectory Prediction techniques, for CD&R*

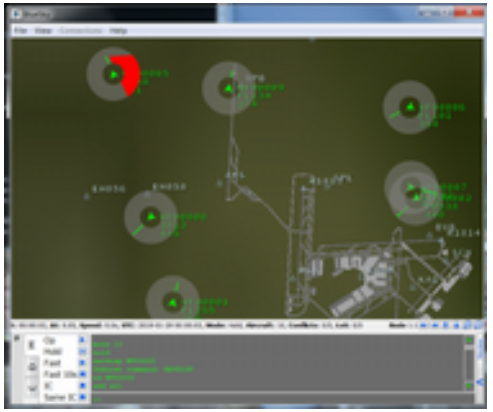
- **Theme 3: GA CNS -** How can we improve the safety of growing GA?
  - *Improved CNS/ATM dev & flight test for today and future GA*

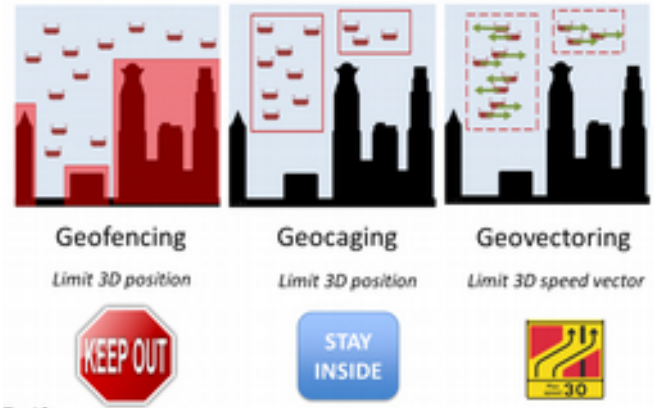
- **Theme 4: UAV CNS -** How to mature UAVs systems and applications?
  - *Pioneer use cases and prototype system development, flight tests*
  - *Integration into ATM system*

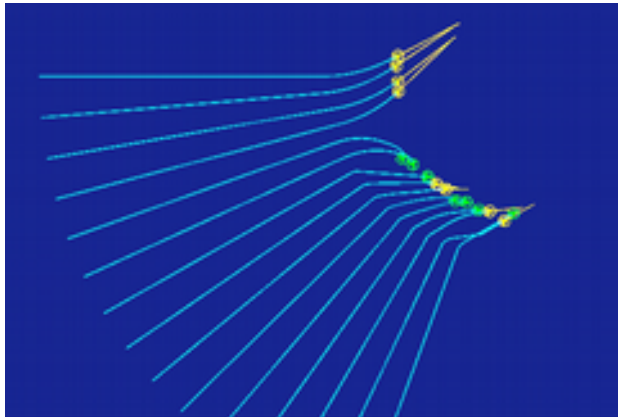
- **Theme 5: Schiphol/NL related CNS/ATM**
  - *Advanced CNS/ATM for the mainport and other topics currently relevant for NL*

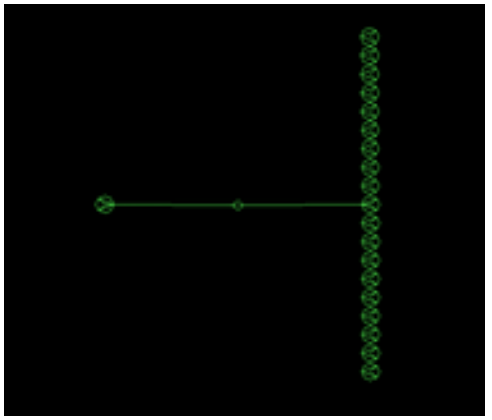
Tools & Concepts we use:

- Big Data
- BlueSky Open ATM simulator incl. Open Data models
- Airborne Separation algorithms: MVP & SSD-based.
- Capacity Analysis & Geovectoring concept

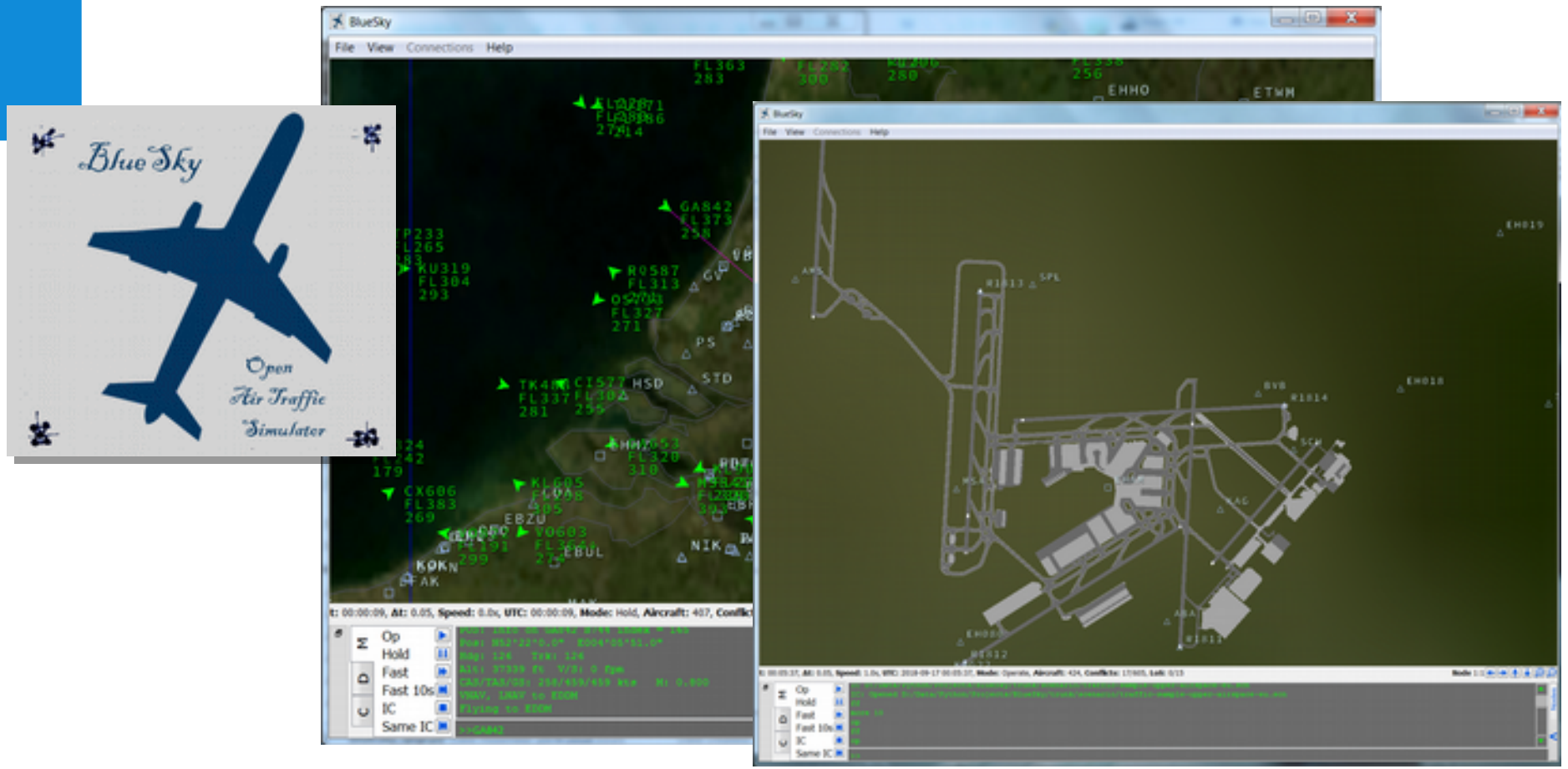








Theme 1: Foundation of ATM
Topic: Open Source/Open Data



BlueSky Open ATM Simulator: https://github.com/ProfHoekstra/bluesky

Traffic factors driving safety and efficiency

- Example for a specific airspace design:

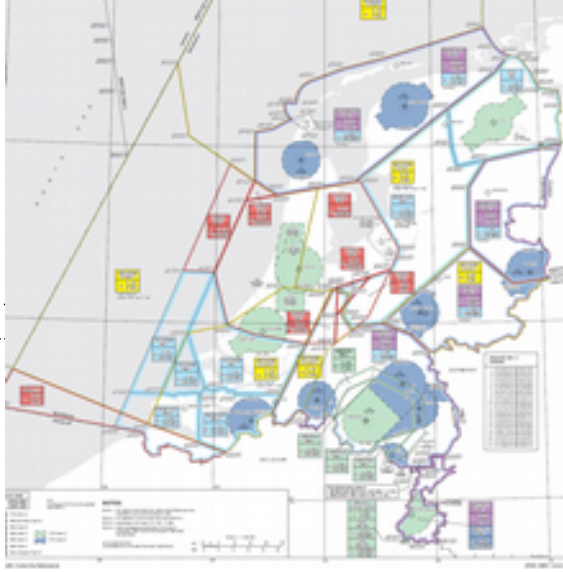
$$CR_{global} = \left(\frac{1}{2}N(N-1)\right)\frac{2R \cdot t_{lookahead}}{A} \cdot E(V_{rel})$$

$$\text{with } E(V_{rel}) = \left(\frac{8V}{\alpha}\left(1 - \frac{2}{\alpha}\sin\left(\frac{1}{2}\alpha\right)\right)\right)$$

More general:

- CAMDA development into Traffic & Airspace Analysis methods

Scenarios &
Objectieve maten voor luchtruim



- Wiskundige maat voor veiligheid en efficiency
- Niet volledig, wel objectief
- Vergelijken van verschillende luchtruimindelingen
- Vergelijkbaar met maten als ‘convergentie’ maar specifieker
- 3D metric, maakt gebruik van big data & simulatie voor validatie & callibratie

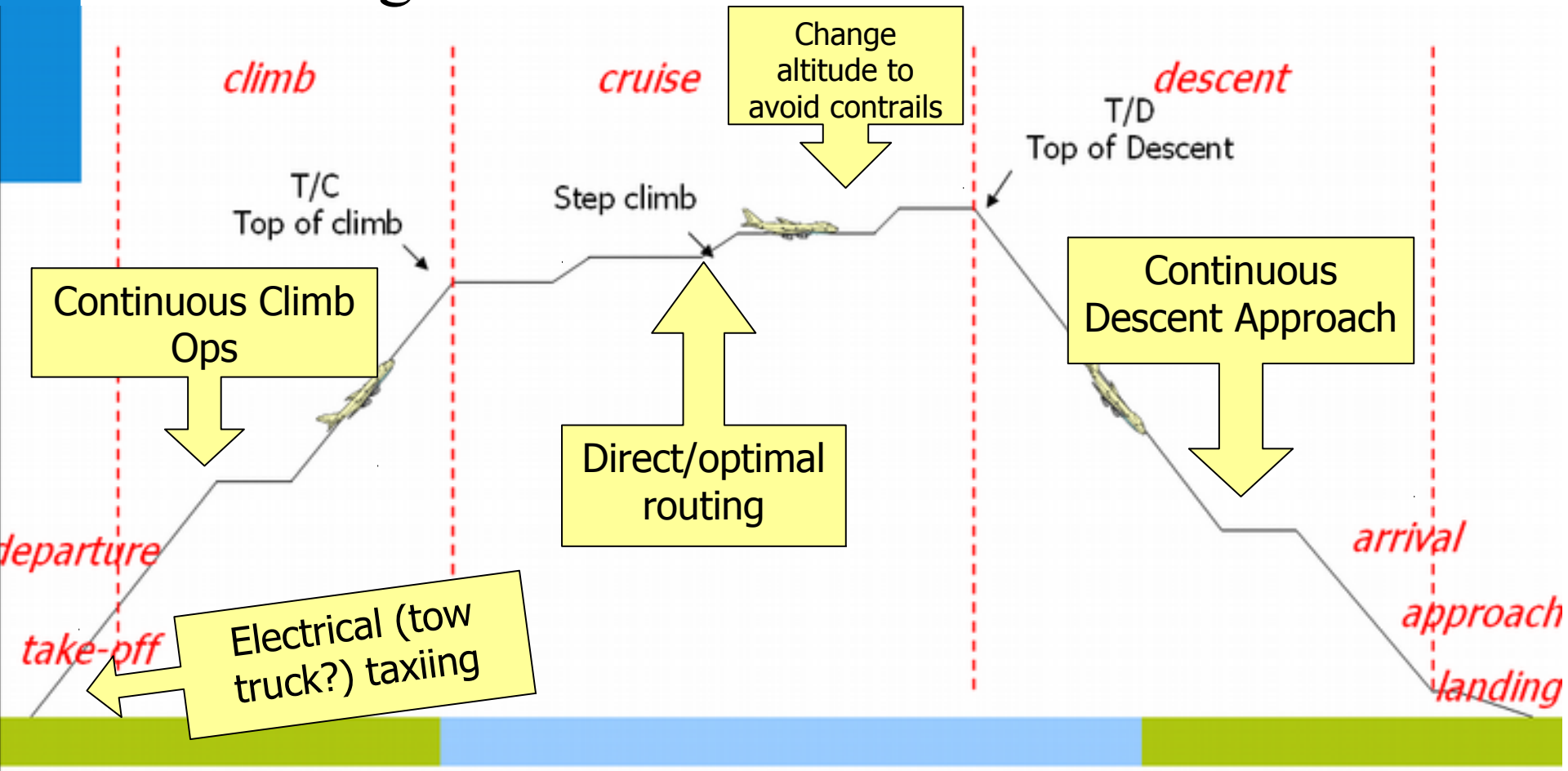
Examples foundation results

- **Traffic scenarios: Past, Present & Future**
  - Repository & Platform: **BlueSky** Open Air Traffic Simulator https://github.com/ProfHoekstra/bluesky (contains also a Wiki and manual)

- **Traffic (Big) Data Analysis**
  - Analytical method to analyse and compare airspace layout (**CAMDA**), extend to controlled airspace
  - Analysis of **traffic data**: quantified and effect of implementing **CDO and CCO** at Schiphol using real traffic data
  - **Traffic tracks database** http://sil.lr.tudelft.nl **:**
    - **Using SIL** and resulting access to FlightRadar24
    - **Mode S decoding** (ADS-B and Enhanced Mode-S) https://mode-s.org/ (i.s.m. KNMI)

- **UAVs, drones VLL airspace management:**
  - **Geovectoring** protocol as UTM element
  - **DREAMS UTM services** for SESAR

How can Air Traffic Management contribute to green aviation?



Electrical taxiing / tow truck

- KLM: B 737 uses 200 000 litres fuel for taxiing alone
- WheelTug: electrical device on nose wheel 140 kg
- TU impact study tow truck (Soepnel MSc thesis, 2015)

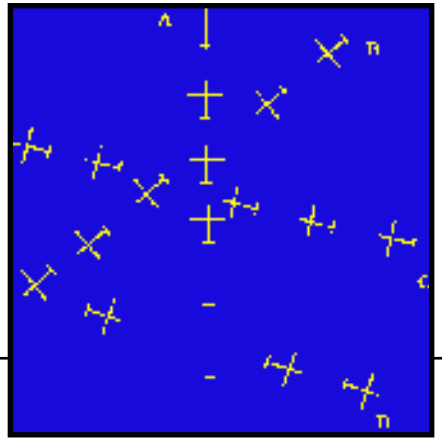
ATM history: Airways

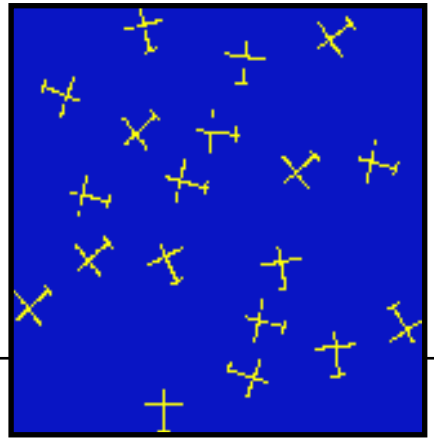
- 1931: Airway Bulletin 1 : Airways (coloured)
- Airway system: beacon lights 10 – 15 miles apart
- Concrete painted arrows with bright yellow
- Intermediate landing files 30-50 miles apart

Airways still in use

First step: Free Route Airspace

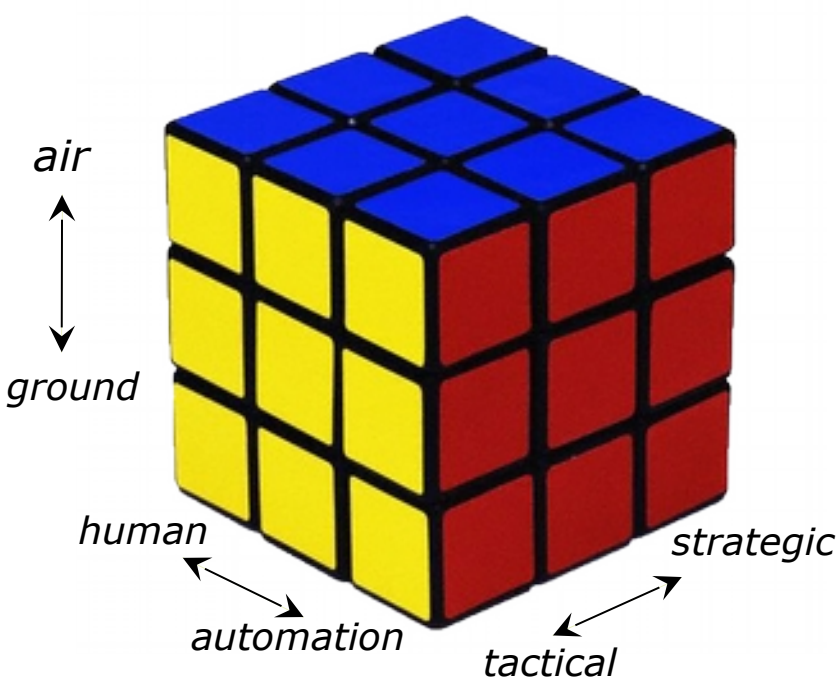
- Ties into airspace design
- Military airspace
- Europe: Functional Airspace Blocks (FABEC)
- Nationally: Redesign Airspace
- Upper airspace (en-route): direct routing in near future





Direct/optimal routing and separation assurance

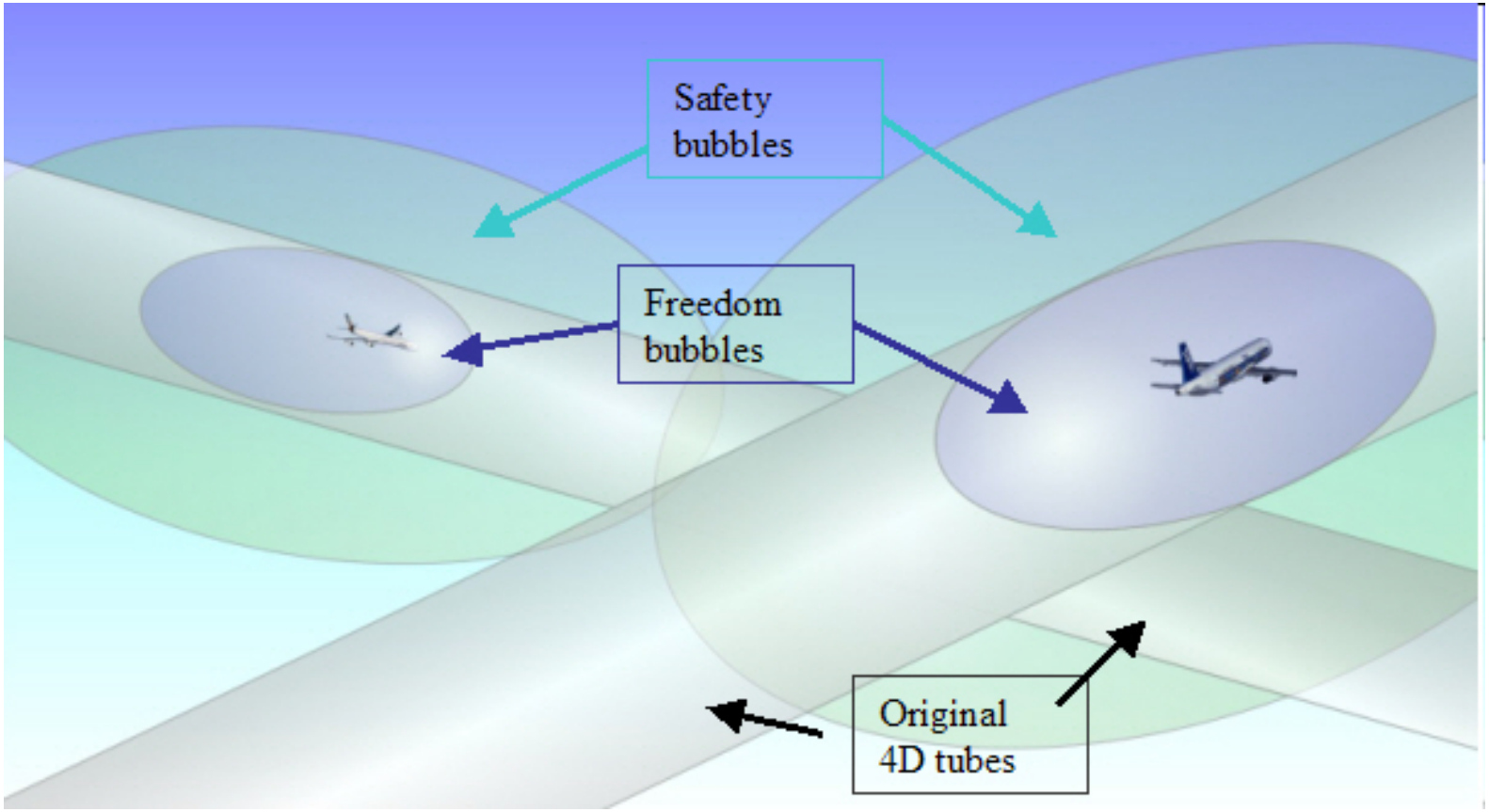
- Who does what and when?



Flight phase dependent

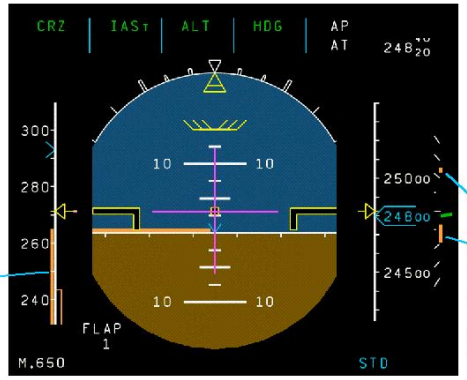
- Taxiing
- Take-off
- Climb
- Cruise
- Descent
- Approach
- Final Approach
- Landing
- Taxiing

Centralisatie: 4D bubbles



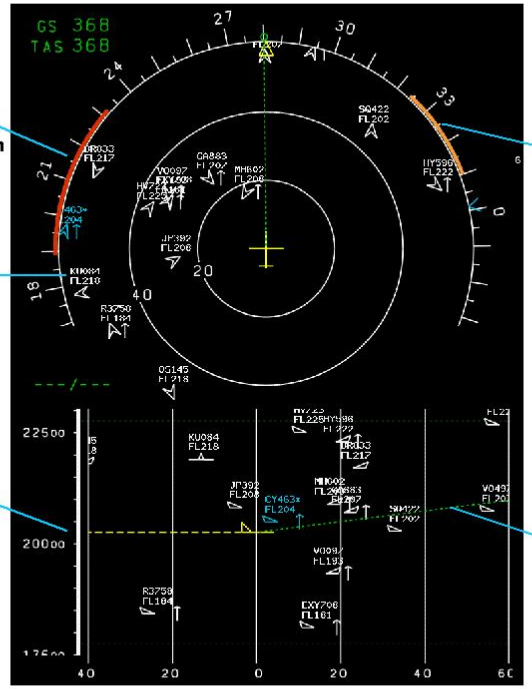
Predictability? At what costs?

Of juist decentralisatie?



Predictive ASAS speed leading to conflict within 3 - 5 min

Predictive ASAS vert. speed leading to conflict within 3 - 5 min



Predictive ASAS track leading to conflict within 3 min

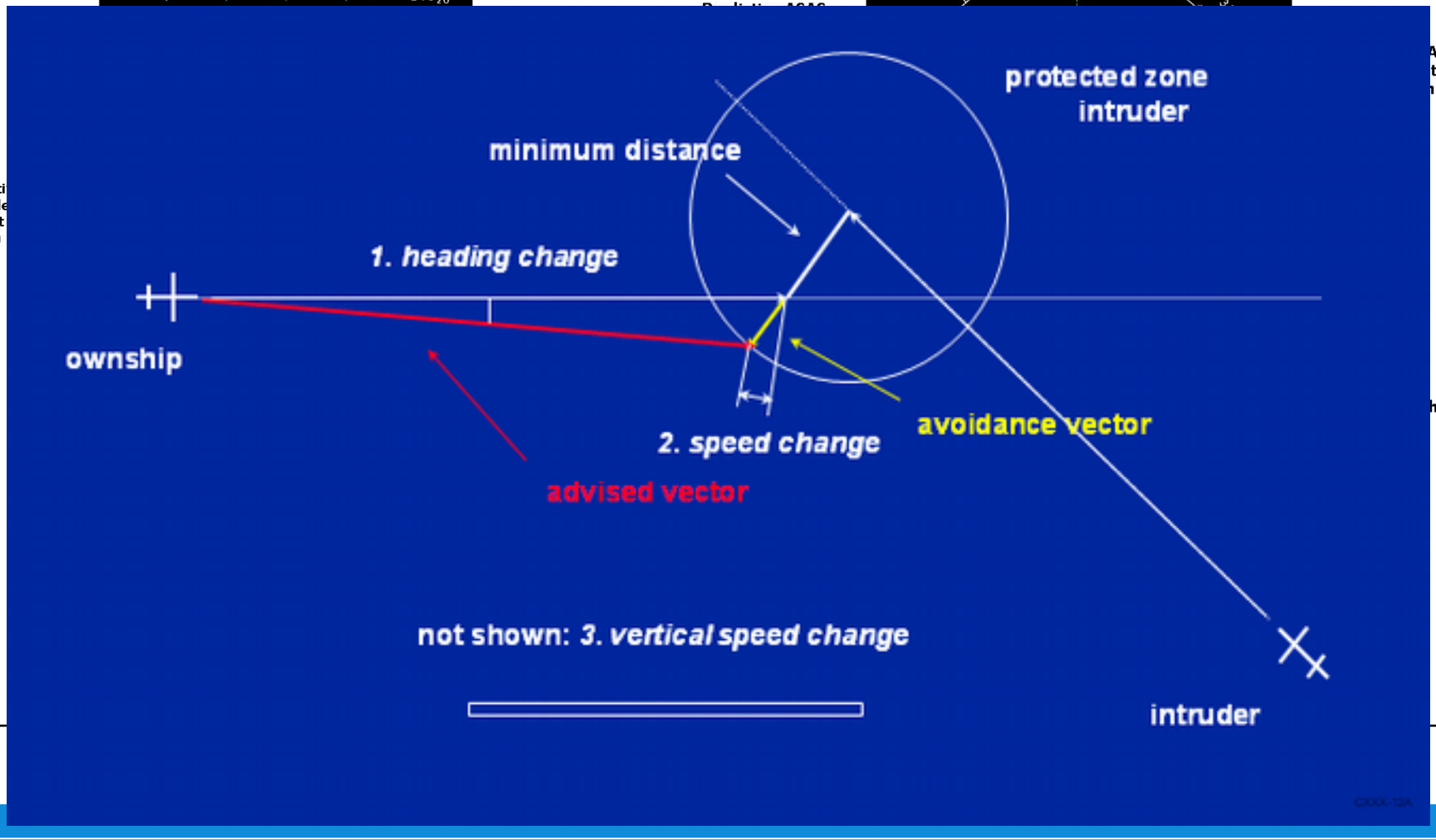
Predictive ASAS track leading to conflict within 3 - 5 min

Traffic symbol:
- position
- track
- climbing/descending
- call sign
- ground speed (not shown)

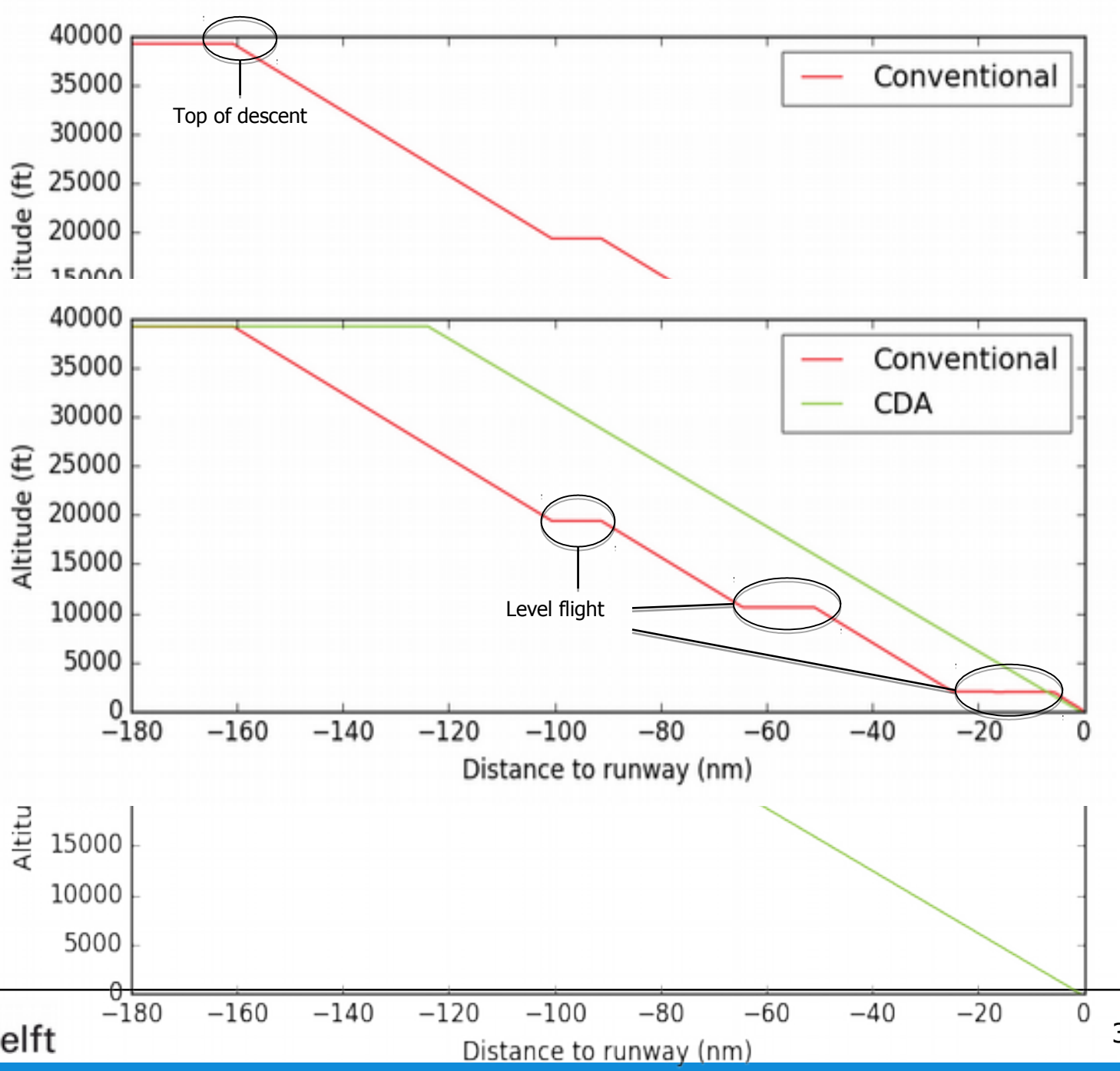
Vertical display

Predicted flight path of ownship

Of juist decentralisatie?

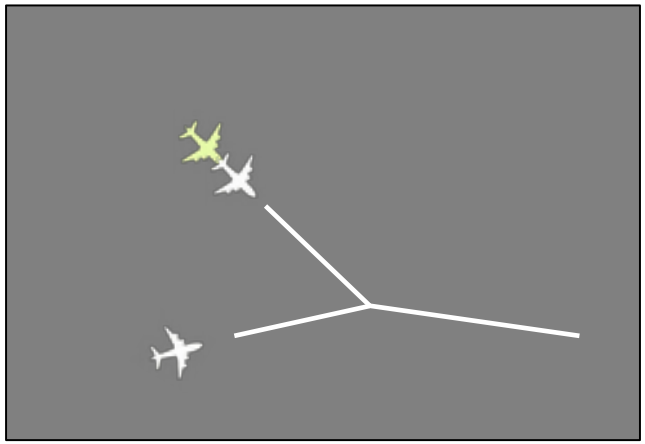


Metafoor: rondweg


Top of descent
Conventional
Altitude (ft)
Conventional
CDA
Level flight
Distance to runway (nm)
Distance to runway (nm)

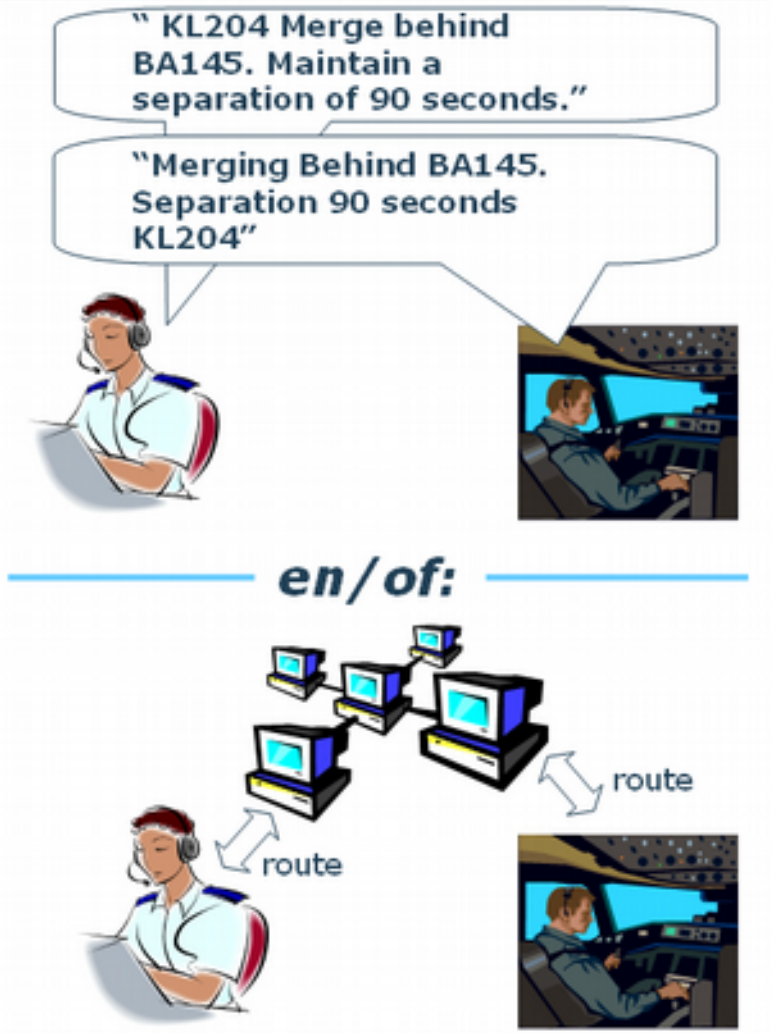
Continuous Descent Operations

- Diminished deceleration capabilities
- Delay absorption is not possible once in CDA
- Increased landing interval



Ghosting
Merging & Spacing

Approach Merging & Spacing with ASAS: "treintjes" te maken



Green activities of CNS/ATM chair

- Some MSc assignments on Green ATM:
  - **What is effect of 100% CCO on Schiphol compared to today?**
    Jeffrey Klapwijk CCO study comparable set-up in co-op with KLM:
    Answer: 16 ton CO_2 per day, 0.1 kg per passenger , today already a lot of continuous climb operations
  - **What is effect of Direct Routing?**
    Big Data Study by Gideon Pappie, Direct routing continental: minimal 2%
  - **Reduce low-level delay absorption** by XMAN? – Alexander Vanwelsenaere
    Answer: Pop-up traffic fraction becomes too large when extending AMAN to achieve a large effect
  - **What is effect of 100% CDO on Schiphol compared to today?** Big Data & Simulation in co-op with KLM, study by Mazin Inaad
    Answer: 338 ton CO_2 per day, 2.12 kg per passenger

Green activities of CNS/ATM chair

- ***Ongoing:***
  Several studies into **direct routing** and **fuel efficiency** increase, also for **new vehicles** like electric VTOL, UAVS in urban airspace (replacing road transport) of UAV geovectoring

- ***Planned new MSc assignments:***
- New vehicle types (new altitudes?):
  What is effect on ATM when traffic is a mix of electrical, hydrogen, hybrid, slow and conventional fossil fuel aircraft?
  (Fixed arrival routes? Late merging? CDO?)

- SESAR:
  What is the environmental cost of focus on predictability?
  Predictability incl. strategic de-confliction by 4D TBO is currently key element in Dutch and SESAR ATM vision?

Repositories scenario/data

- **Traffic scenarios: Past, Present & Future**
  - Repository & Platform: **BlueSky** Open Air Traffic Simulator https://github.com/ProfHoekstra/bluesky (contains also a Wiki and manual)

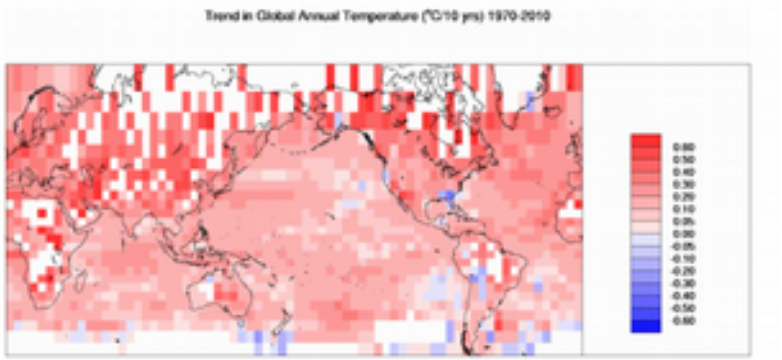
- **Traffic (Big) Data Analysis**
  - Analytical method to analyse and compare airspace layout (**CAMDA**), extend to controlled airspace
  - Analysis of **traffic data**: quantified and effect of implementing **CDO and CCO** at Schiphol using real traffic data
  - **Traffic tracks database** http://sil.lr.tudelft.nl **:**
    - **Using SIL** and resulting access to FlightRadar24
    - **Mode S decoding** (ADS-B and Enhanced Mode-S) https://mode-s.org/ (i.s.m. KNMI)

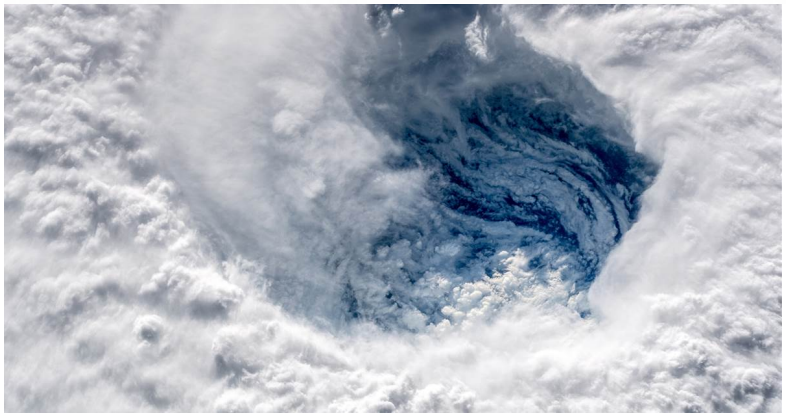
- **UAVs, drones VLL airspace management:**
  - **Geovectoring** protocol as UTM element
  - **DREAMS UTM services** for SESAR

Duurzaamheid en ATM gevolgen

- **Korte/Middellange termijn:**
  - Continuous Descent Approaches (CDA)
  - Delegated Separation Assurance:
    - Voorspelbarheid vs emissions ? meerdere routes/bundels?
    - merging & spacing
  - Grotere vliegtuigen

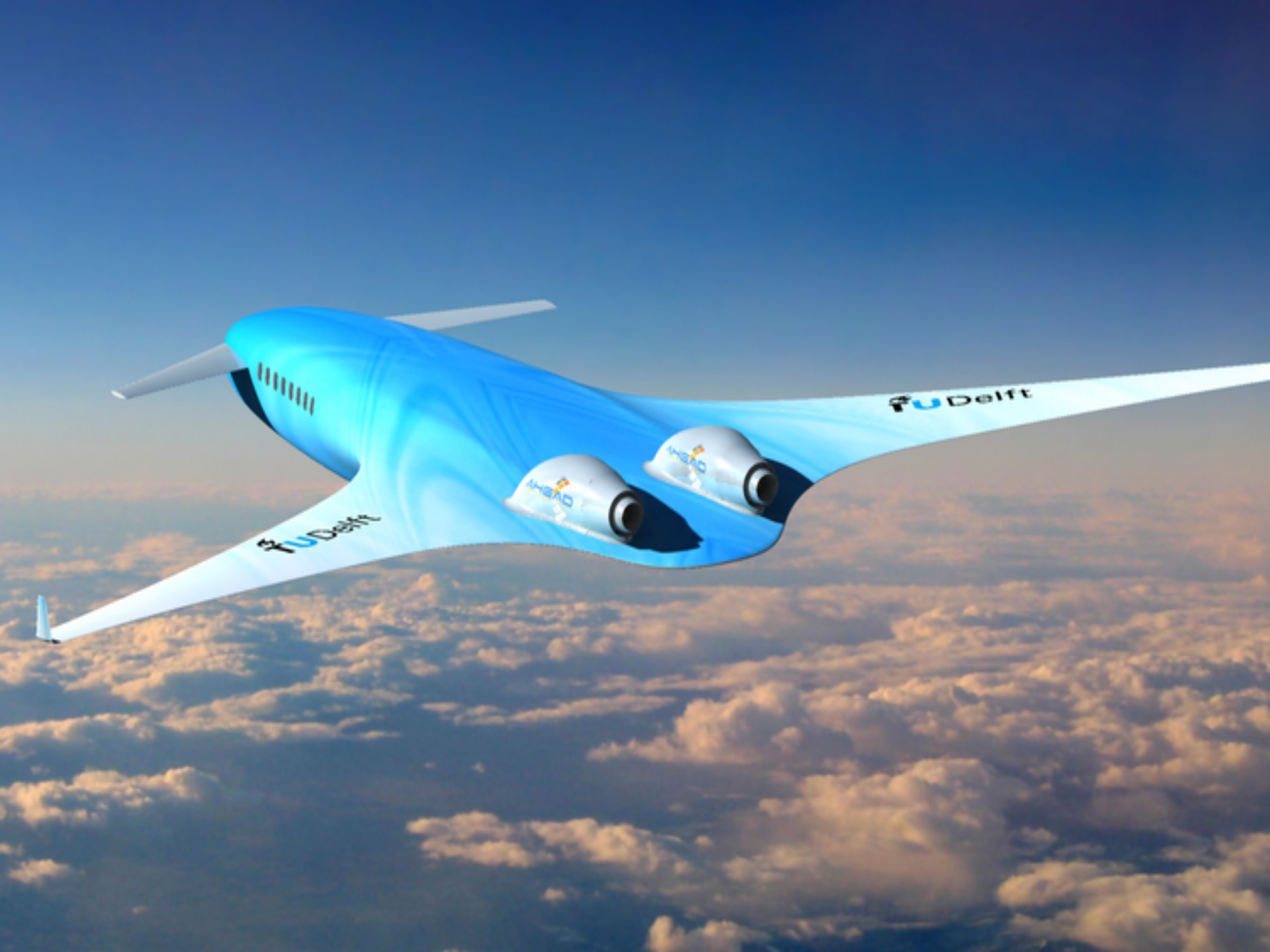
- **Lange termijn:**
  - Einde aan de groei luchtverkeer
  - Nieuwe voertuigen
    - Package delivery by drone
    - Small electric vehicles (Personal Air Transport?)
    - Waterstof (hoogte-condenssporen)





Resumerend

- Minder vliegen
  - Continentaal: alternatieve vormen
  - Intercontinentaal: minder reizen
- Optimaler vliegen:
  - Continuous Descent Operations
  - Direct, optimal routing
  - Liever optimaal dan voorspelbaar
- Taken ATCO naar cockpit is een enabler: dit geeft ruimte voor tactische optimalisaties en het maken van 'treintjes'
- Regie overheid, los van stakeholders:
  - Repository: Enabler is onafhankelijke open data en scenarios (incl. level en krimpscenario's)


TU Delft
TU Delft