

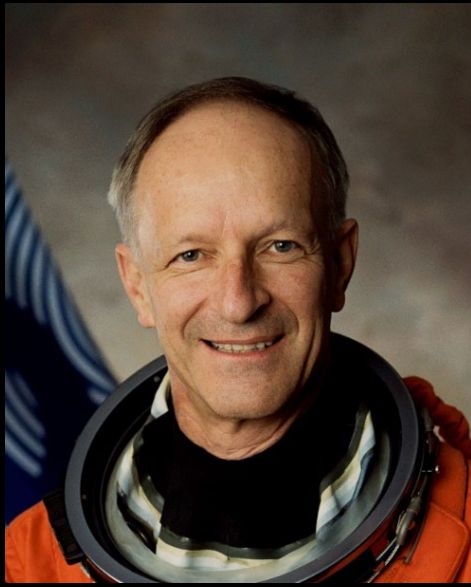
# Wasserstoff in der Luft-und Raumfahrt Hydrogen in Aerospace



Claude Nicollier  
ESA & Space Innovation  
EPFL Lausanne

Ramseyer Anniversary Symposium  
Ittigen  
August 27<sup>th</sup>, 2024

A preliminary

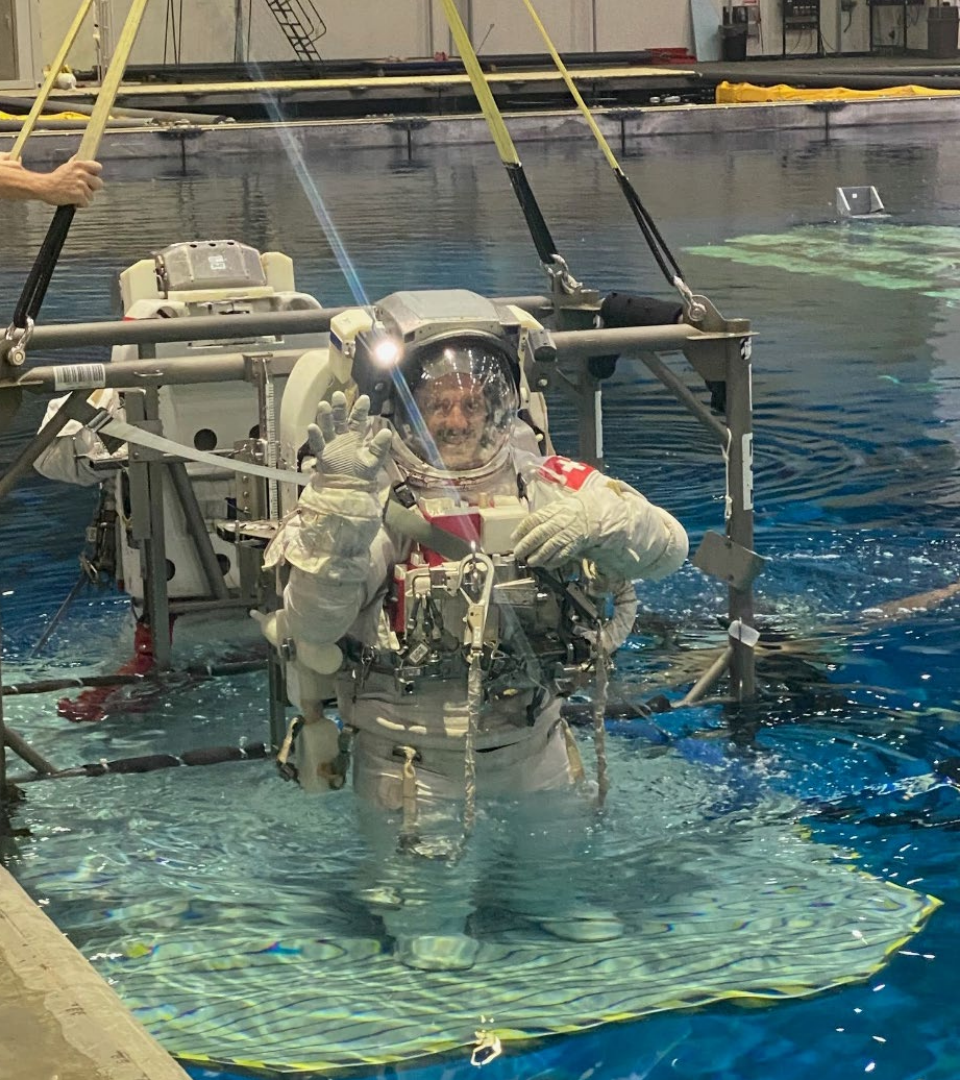


I no longer am the only ESA/Swiss  
astronaut, now we have

**Marco Sieber** →

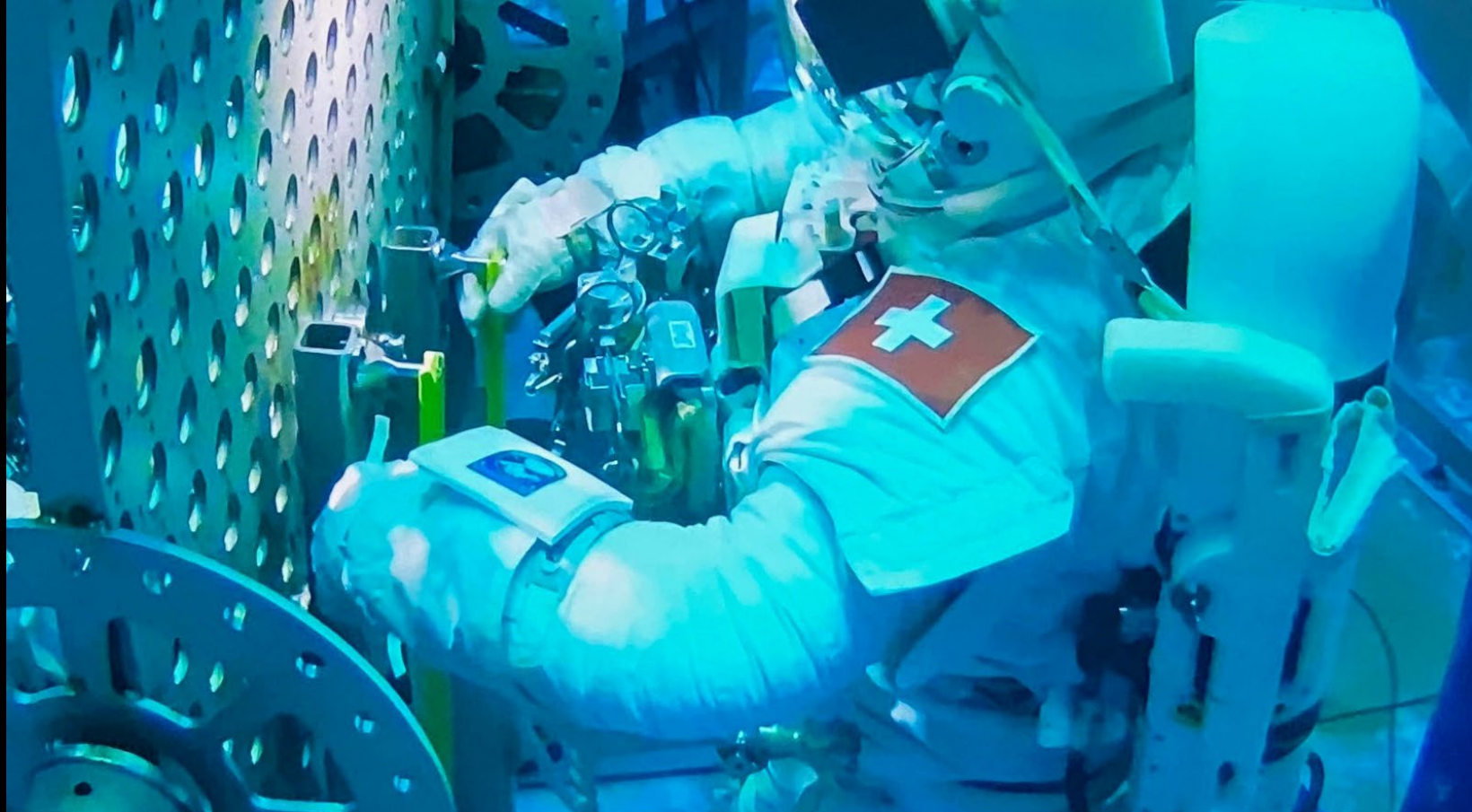
ESA Class on Astronauts 2022

Congratulations, Marco!



Marco Sieber starting his first suited run in the NBL (Neutral Buoyancy Lab) near the Johnson Space Center in Houston, Texas, August 2<sup>nd</sup>, 2024





Practicing the skills of spacewalking in simulated zero-g conditions



## Outline

- Sustainable aviation
- Going into space, with or without hydrogen
- The near future energy sources on Earth, in the air and in space, with a clear consideration of sustainability

Our Universe is essentially a hydrogen universe!  
75% of all mass in the Universe is hydrogen, and 90% of all atoms in the Universe are hydrogen atoms



Sustainable aviation



**Fly Net Zero** is the commitment of airlines to achieve net zero carbon by 2050

At the 77th IATA General Meeting in Boston, in October 2021, a resolution was passed by member airlines committing them to achieving **net-zero carbon emissions from their operations by 2050**. This pledge brings air transport in line with the objectives of the Paris Agreement to limit global warming to below 2°C.

65% of this objective should be reached by using SAF or Sustainable Aviation Fuel, the rest through new technologies (in particular the use of hydrogen in fuel cells or direct combustion) and offsetting/carbon capture

29/10/2021

First flight of an Airbus A319neo  
using 100% SAF





In parallel, the electrification of general aviation is continuing successfully

A pioneer: Solar Impulse, round the world using solar power  
in 2025-2026





We have now many light airplanes using electrical propulsion, for instance the Alpha Electro from Pipistrel (Slovenia)



We also have the H55 company, based in Sion and created by André Borschberg - goal: electrification of light training and transport airplanes



An obvious source of electrical energy (through a fuel cell),  
or for no-emission propulsion through combustion  
in a jet engine is:



One condition: **GREEN H<sub>2</sub>**

# The “color” of hydrogen

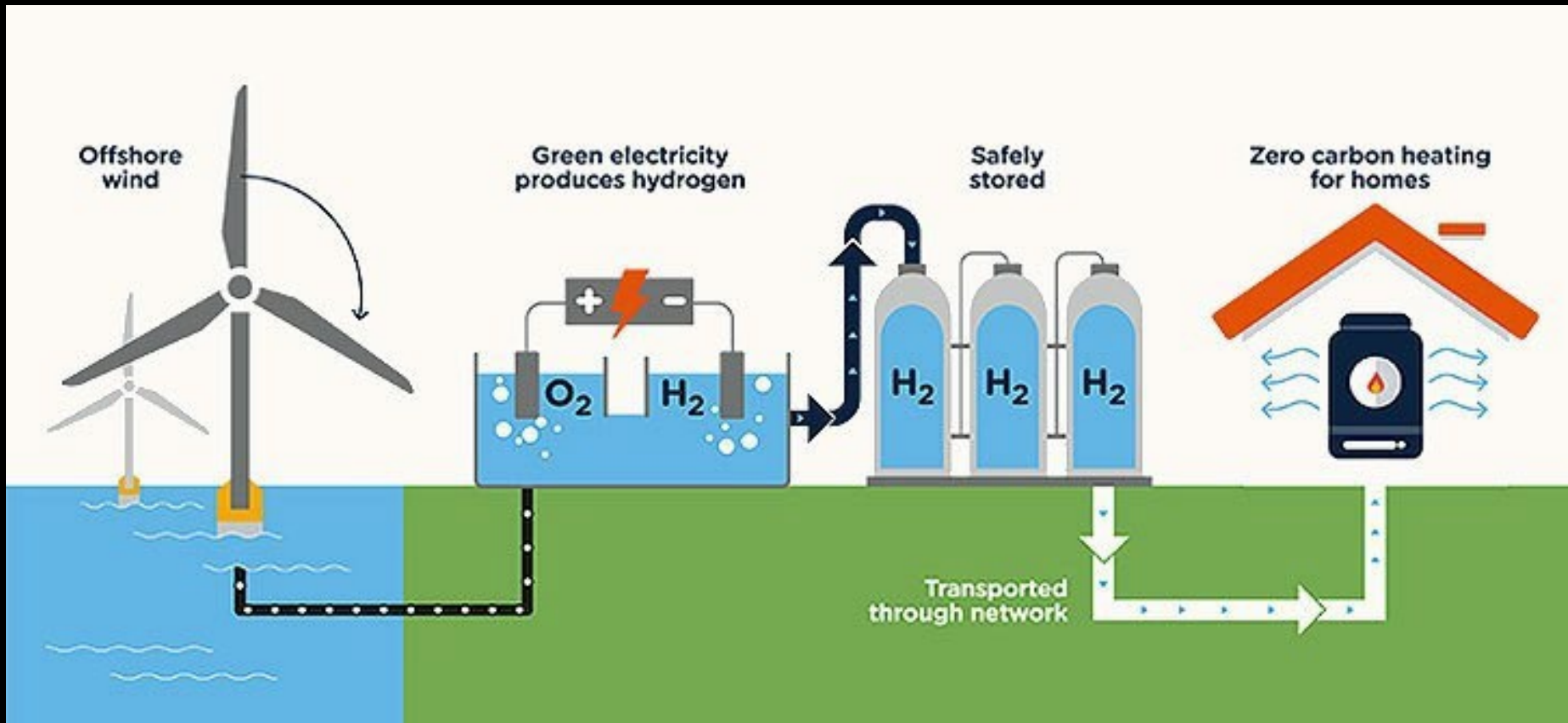
Different methods of producing hydrogen are often referred to by certain colours:

**Grey hydrogen** – Produced by mixing fossil gas with steam. Releases large quantities of CO<sub>2</sub>.

**Blue hydrogen** – Produced using the same method as grey hydrogen, but with carbon emissions supposedly captured and stored underground. Yet to be proven at any significant scale. Both grey and blue hydrogen are more accurately called ‘fossil hydrogen’.

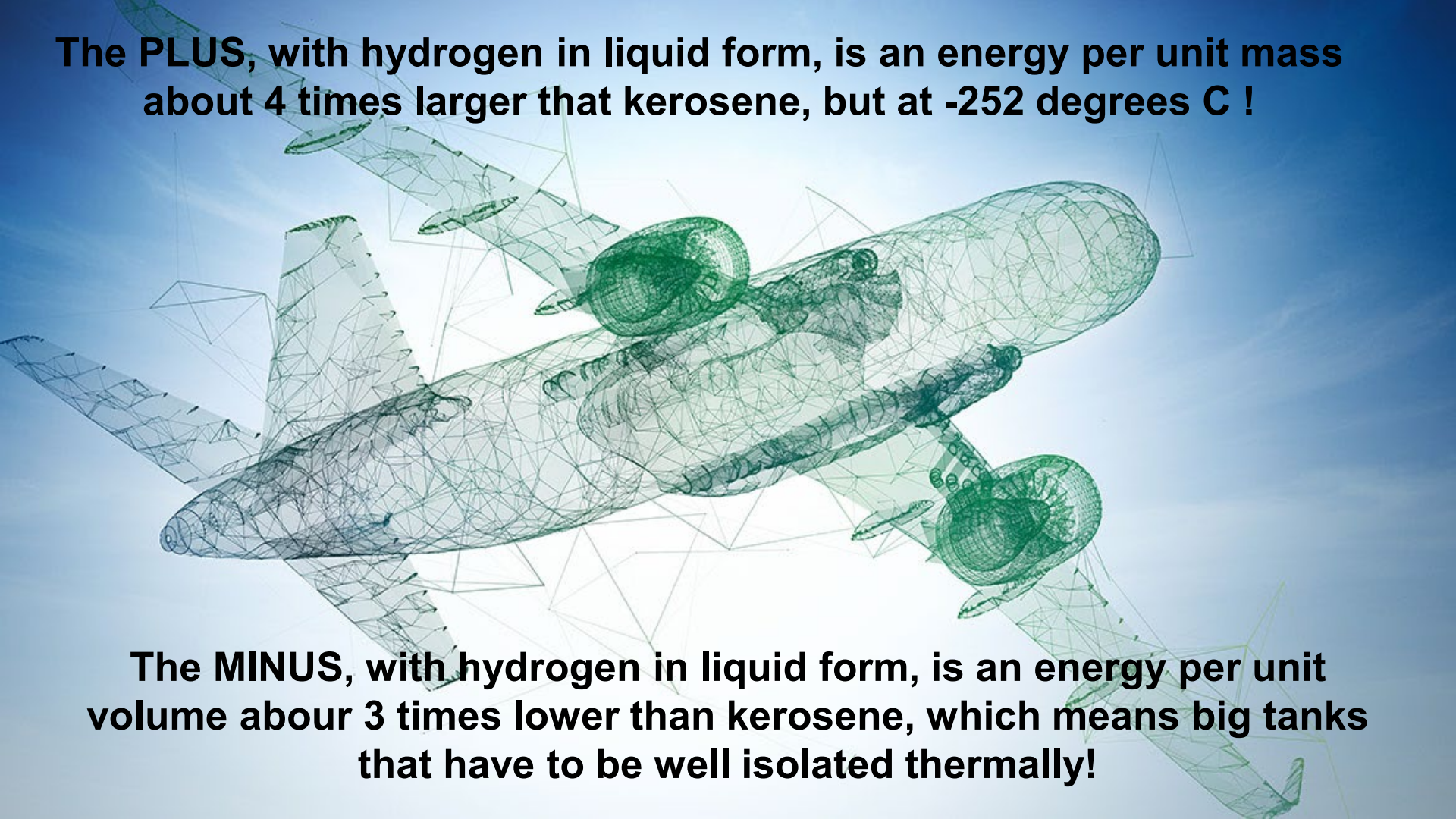
**Green hydrogen** – Produced by passing electricity generated from renewable sources through water. Results in very low carbon emissions.





Green hydrogen production

**The PLUS, with hydrogen in liquid form, is an energy per unit mass about 4 times larger than kerosene, but at -252 degrees C !**



**The MINUS, with hydrogen in liquid form, is an energy per unit volume about 3 times lower than kerosene, which means big tanks that have to be well isolated thermally!**



Airbus is working on future airliners using hydrogen combustion in jet engines



A blended wing/fuselage allows to carry a larger volume of liquid fuel for a given size of the airplane, and is also efficient from an aerodynamic point of view

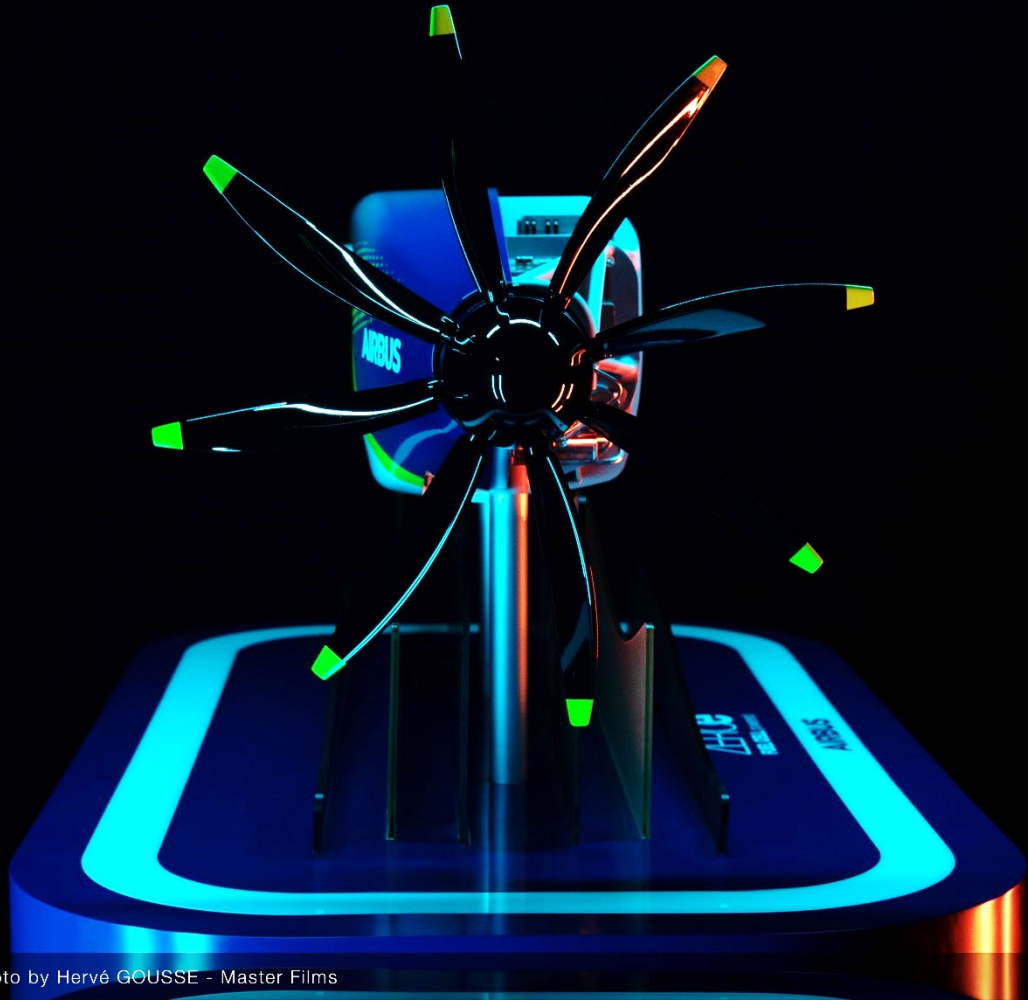




An Airbus concept  
I am not sure the passengers will really like it, but...



Airbus prepares tests of an aircraft propulsion system of megawatt power class, fed by a fuel cell



# Destinus project - unmanned hypersonic point-to-point high altitude transfer (Payerne Aeropole-based)



Destinus  
← prototype

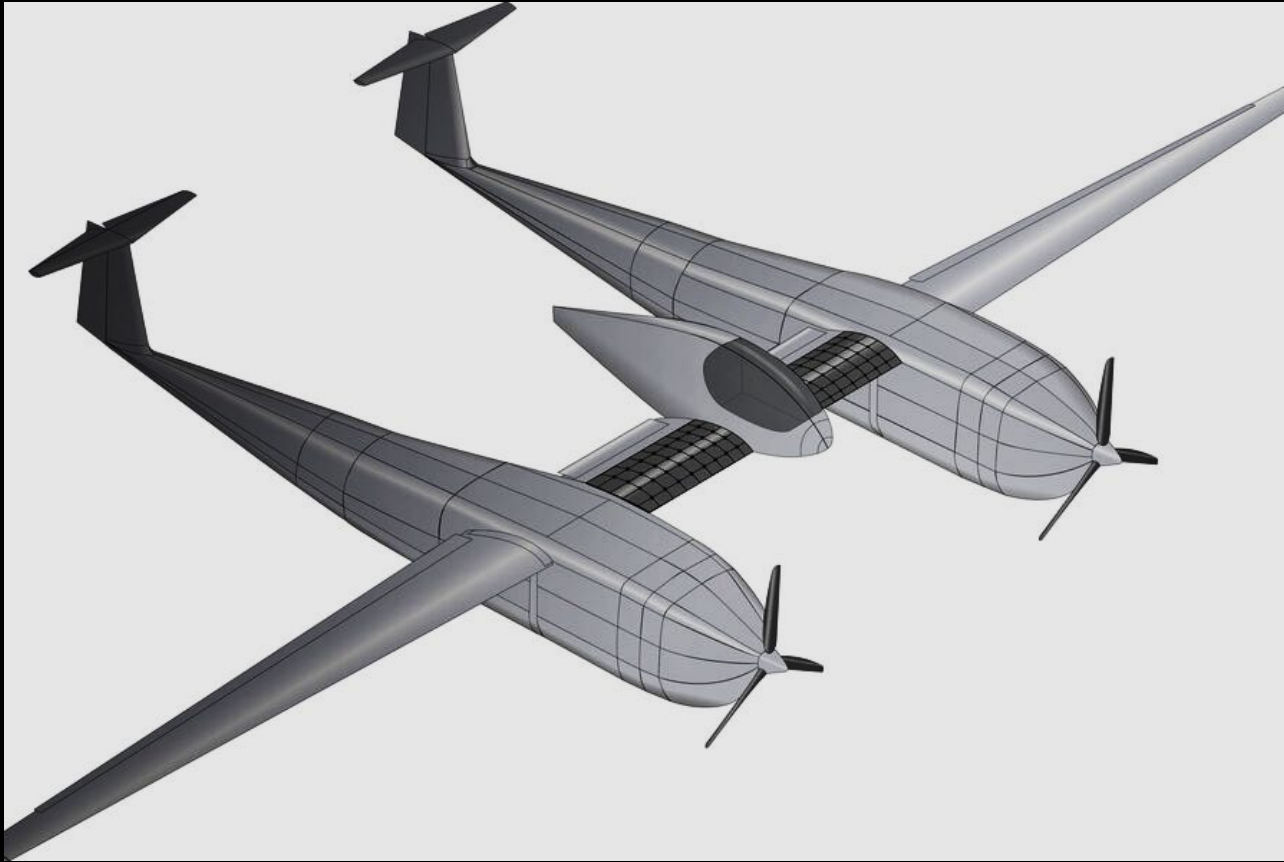
Destinus final →





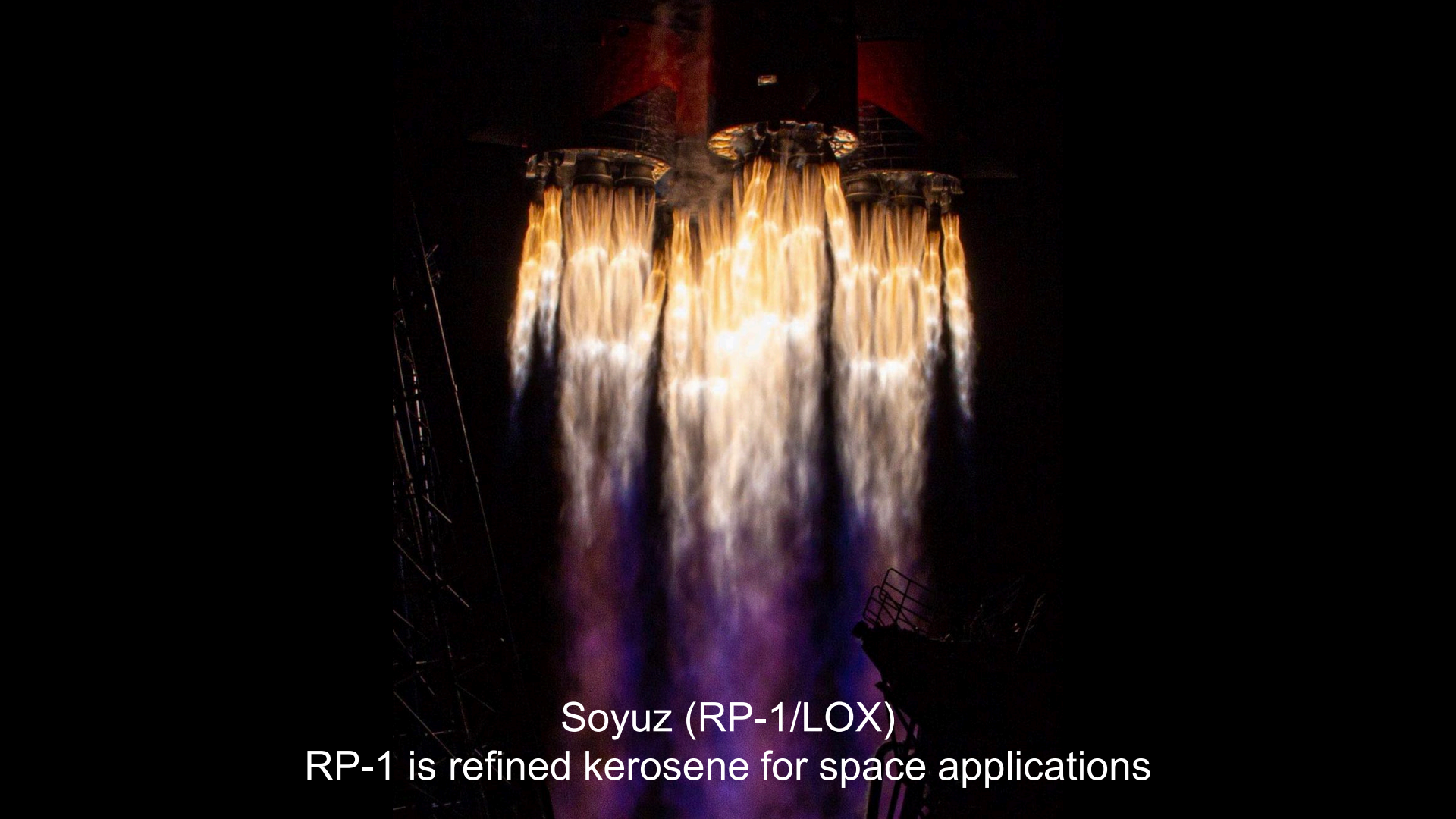
"The propulsion system for DestinUS will incorporate a **kerozene - fueled turbojet engine** in conjunction with a **liquid hydrogen - fueled ramjet**. They are also developing plans to trial a fully hydrogen-based system for both turbojet and afterburner."

"The demonstrator is equipped with a liquid hydrogen tank and an innovative feed system that features an electric pump. DestinUS 3 is on track for its inaugural subsonic flight in 2024, with supersonic flight campaigns to follow in late 2024."



An idea of Bertrand Piccard: Round-the-world in 9 days with an electrical aircraft demonstrator using hydrogen fuel cells

Going into space!



Soyuz (RP-1/LOX)

RP-1 is refined kerosene for space applications



# Long March/Shenzhou (RP-1/LOX)



Atlas V (RP-1/LOX)



# SLS

Space Launch System  
For the Moon to Mars Artemis program

First stage is essentially using  
Shuttle technology  
(4 RS-25 and 2 SRBs)

Reduction of development cost,  
But increased of operationsl cost  
compared to a higher tech design



# SpaceX Starship (CH<sub>4</sub>/LOX)







SpaceX Heavy Booster/Starship CH<sub>4</sub>/LOX  
Very promising future human-rated launcher/spacecraft for Moon  
and Mars exploration



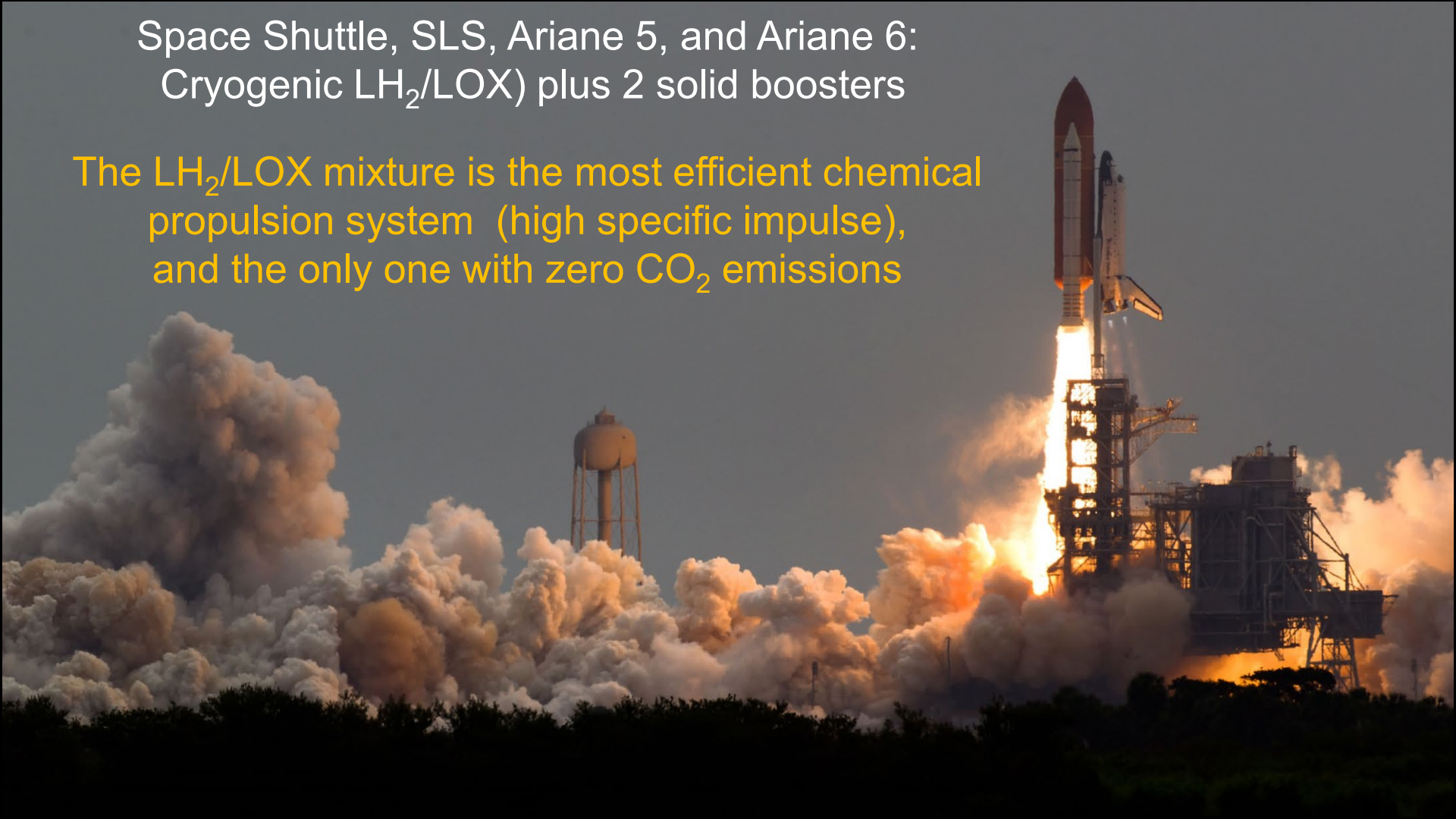
Test of Starship second stage recovery, Boca Chica, Texas, 2021



New Shepard (suborbital)  
of Blue Origin  
With a BE-3 (LH<sub>2</sub>/LOX) rocket engine  
No CO<sub>2</sub> emissions!

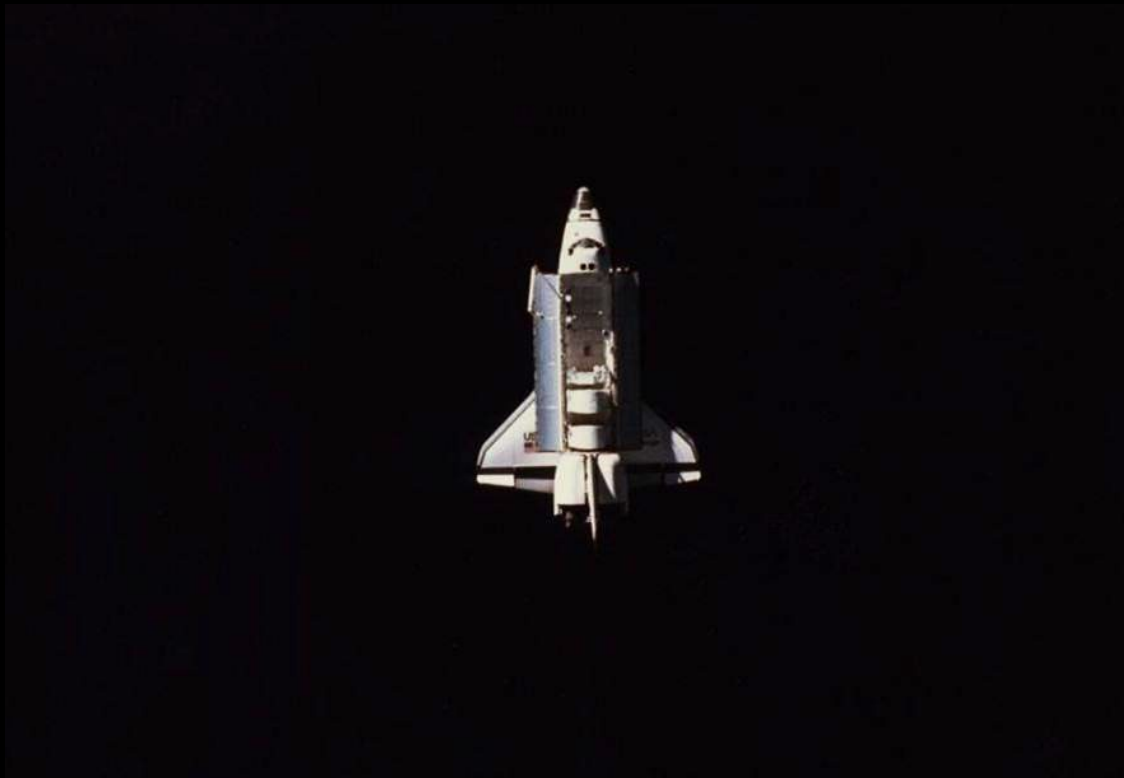
Space Shuttle, SLS, Ariane 5, and Ariane 6:  
Cryogenic LH<sub>2</sub>/LOX) plus 2 solid boosters

The LH<sub>2</sub>/LOX mixture is the most efficient chemical propulsion system (high specific impulse), and the only one with zero CO<sub>2</sub> emissions

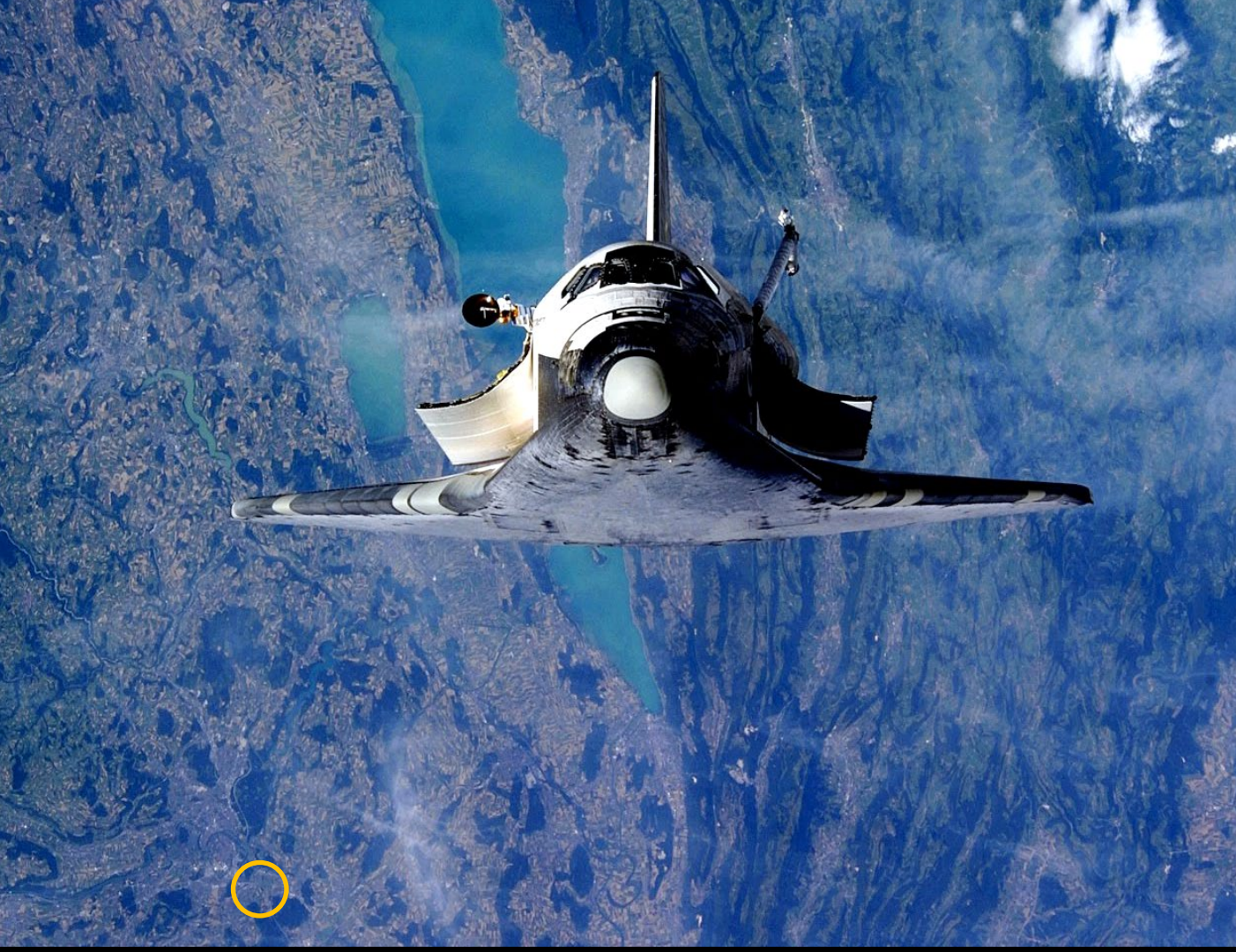








On-orbit at 28'000 km/h



Shuttle nearly  
over Ramseyer  
at Ittigen, at  
400 km altitude  
in July 2005





SLS lift off on the Artemis 1 mission in November 2022



The ORION  
capsule, Moon  
and Earth!

December 2022





# The near future energy sources for sustainability

## On Earth

Fusion (some day), plus renewables  
Hydraulic, solar, wind, geothermal

## Mobility on Earth

Electrical with batteries or fuel cells

## Mobility in the air

Electrical with fuel cells or H<sub>2</sub> combustion

## Propulsion for launch and in space

Cryogenic H<sub>2</sub>/LOX

CH<sub>4</sub>/LOX for some applications (Mars)

Nuclear propulsion

Ion or electric propulsion when in space only



Thank you for your attention !

