WATER PROPULSION

The ultimate Green Propellant

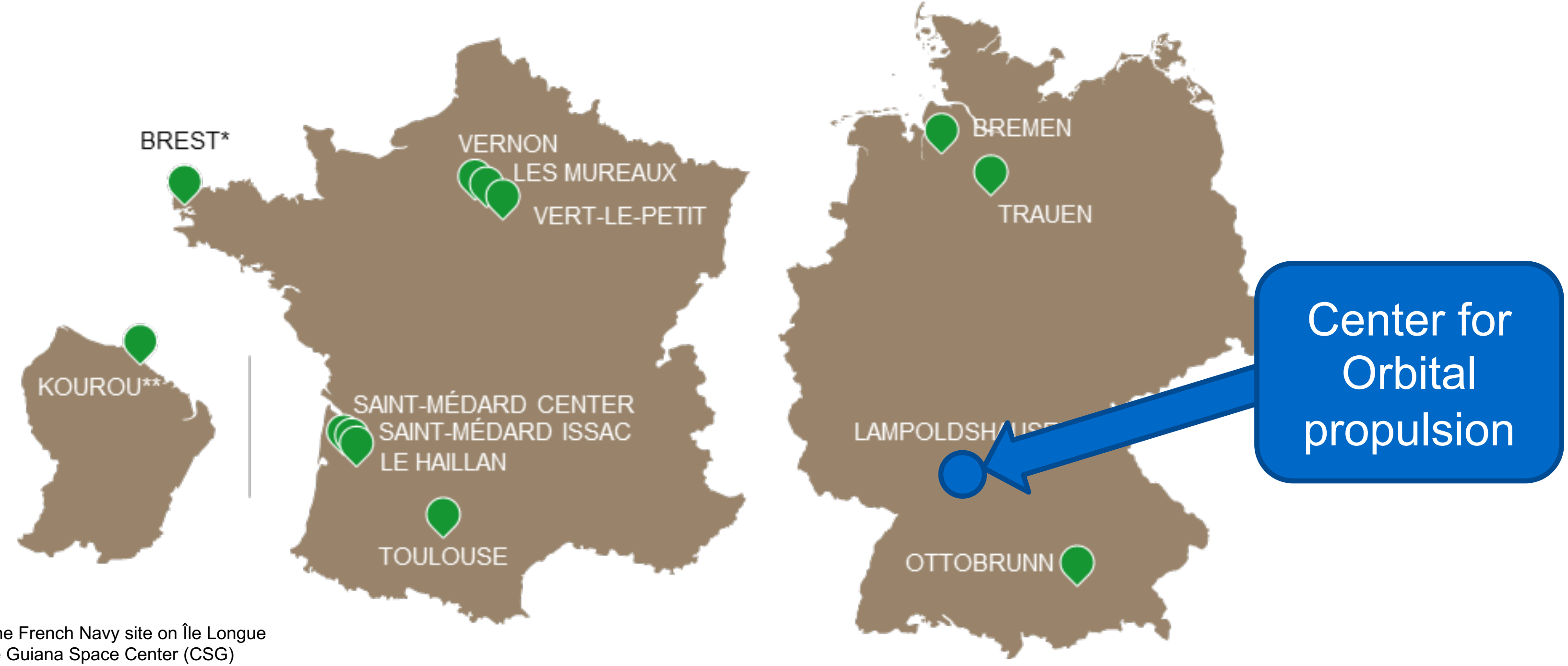
Malte Wurdak, Nicolas Harmansa, Ulrich Gotzig

Clean Space Industry Days, Noordwijk

ARIANEGROUP - LOCATIONS

FRANCE

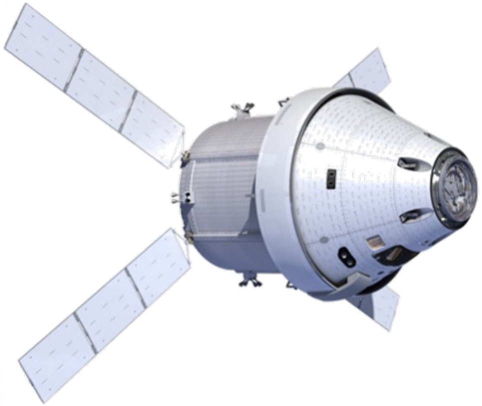
GERMANY

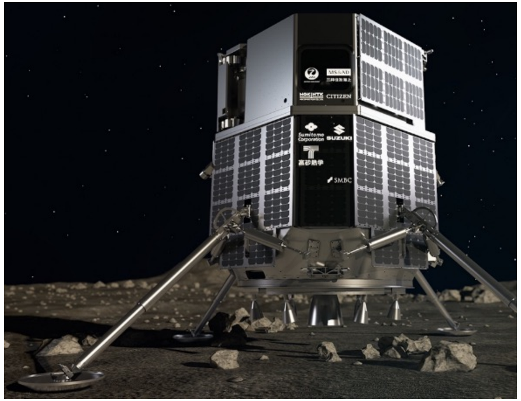


* Secondment to the French Navy site on Île Longue
** Locations on the Guiana Space Center (CSG)

arianeGROUP

ArianeGroup’s Applications in Propulsion





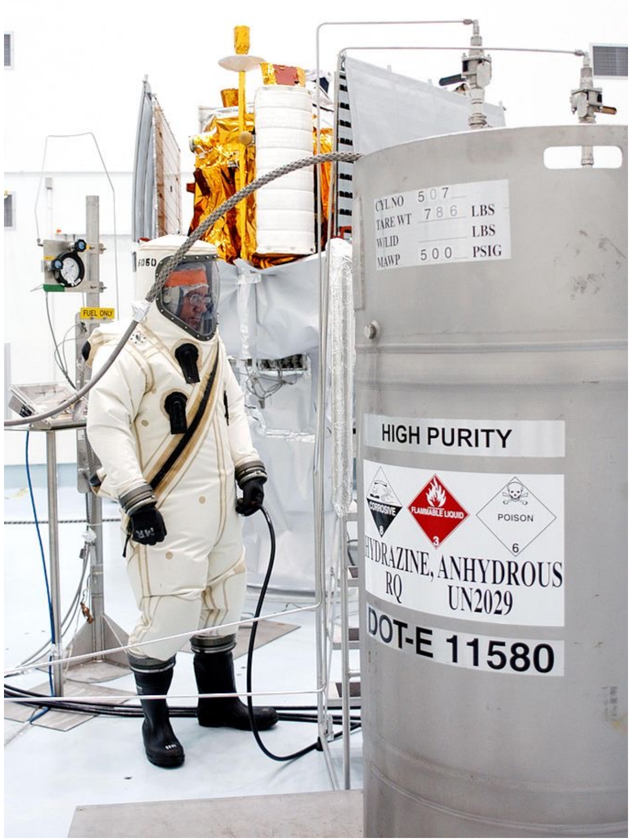
arianeGROUP

A BRIEF EXCURSION IN ROCKET HISTORY

Hydrazine Hydrate „C-Stoff“ ME 163

While $H2O2$ was initially used for rocket propulsion [H. Walther] it was replaced by hydrazine due to its better stability and higher performance.

At that time toxicity was not a real issue …




arianespace
65 P

Motivation for Green Propellants

Economic and Legislative

Advantages

- Lower handling cost
- Fast turnaround times
- Potential higher performance (ISP, density ISP)
- More players in the field

Challenges

- Heritage, Reliability, Performance, Cost
- Availability of system components

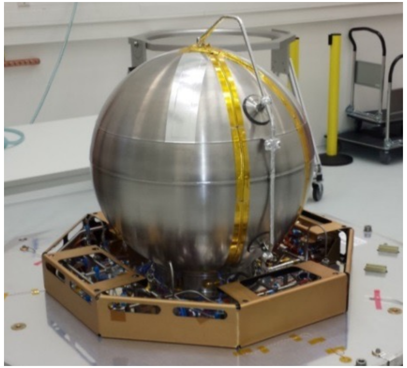
Legislative

- In 2011 Hydrazine was identified as Substance of Very High Concern and included in Europe‘s REACh candidate list with a potential ban of it‘s use – since then no further evolution
- Clean Space

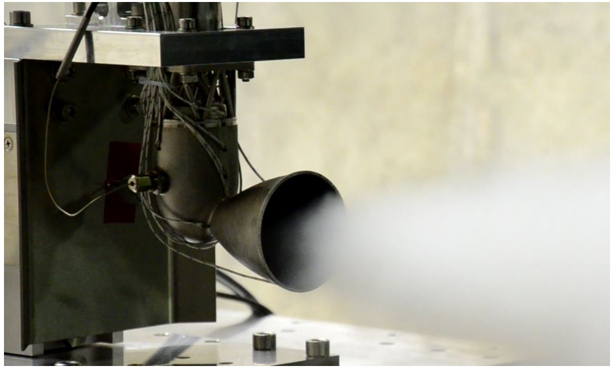
APPLICATIONS AND TECHNOLOGIES
for Space Propulsion in Europe

Application		Existing		Future Technology
Launcher short duration mission	**Roll Control**	Hydrazine	Cold Gas	**Cold / warm gas, H_2O_2**
	Upper Stage	NTO + MMH	LOX / LH_2	**LOX / CH_4,** (Green Biprops)
Satellite long duration mission	**Low Δv**	Hydrazine	(LMP-103S)	**H_2O_2, Electric, Water, N_2O based**
	High Δv	NTO + MMH	Electric	**Green Bipropellants**
Exploration long duration high reliable	**Medium thrust Low Δv**	Hydrazine		**LMP-103S, Water N_2O based**
	High thrust High Δv	NTO + MMH		**Green Biprops**

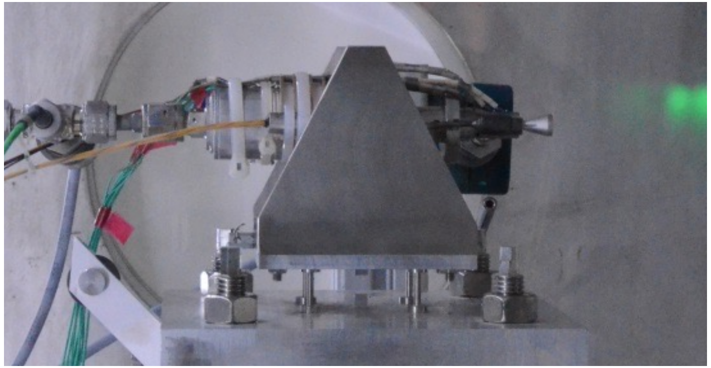
Investigated Technologies at a glance



LMP-103S System



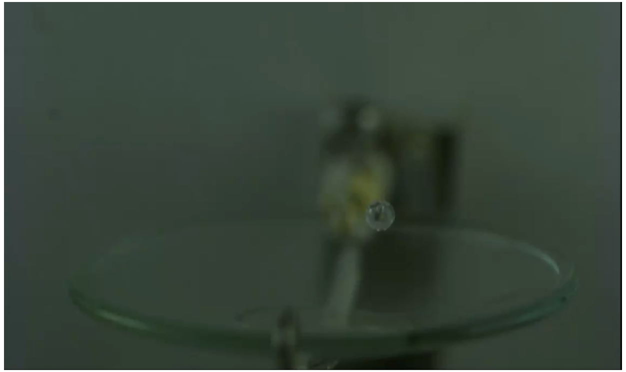
ALM printed 240N H_2O_2 Thruster (87,5%)



1N H_2O_2 Thruster (98%)

Stoichiometric GO_2 / GH_2 Thruster

High Pressure PEM Electrolyzer



Hypergolic Bipropellants (H_2O_2 97%)

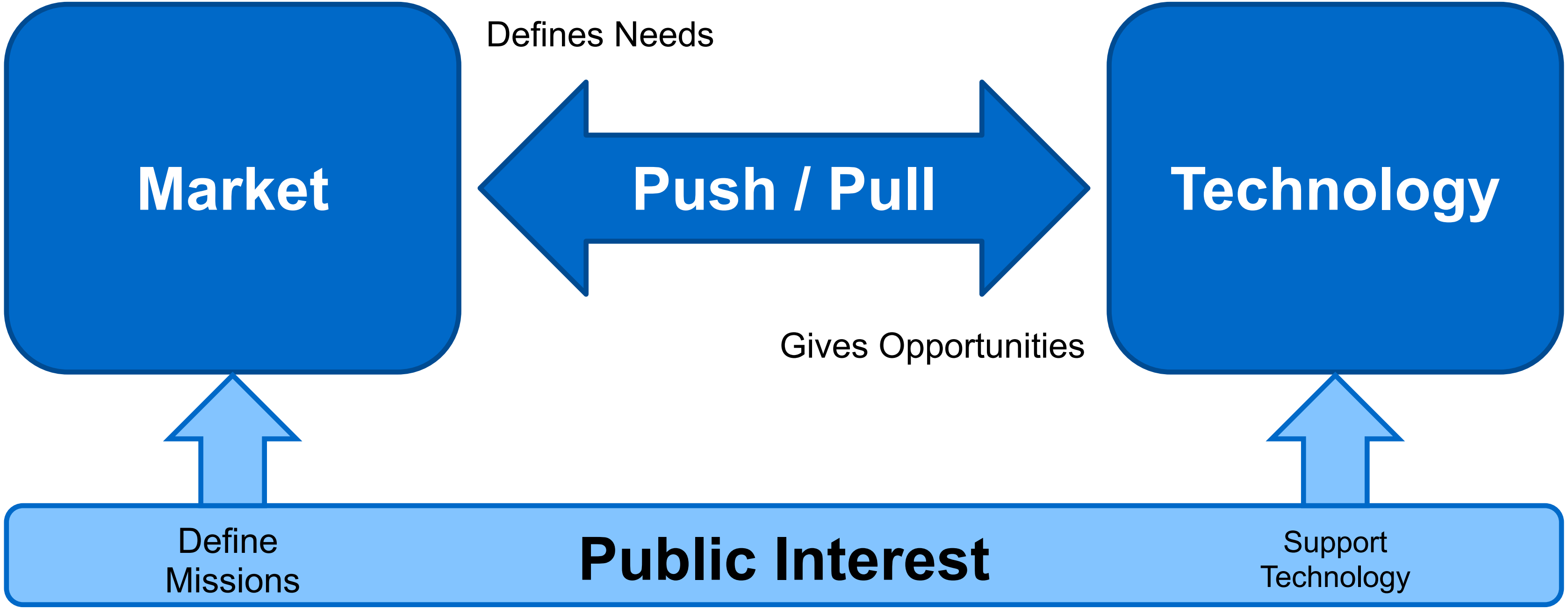
“In the end, SES does not specify the propulsion technology, but specifies the capability, need date and price target.

The satellite vendor presents the most optimal propulsion subsystem(s) to SES for each specific mission”

EPIC workshop 2017

Challenges to bring Green Propulsion into Orbit

Propulsion Needs and Trends



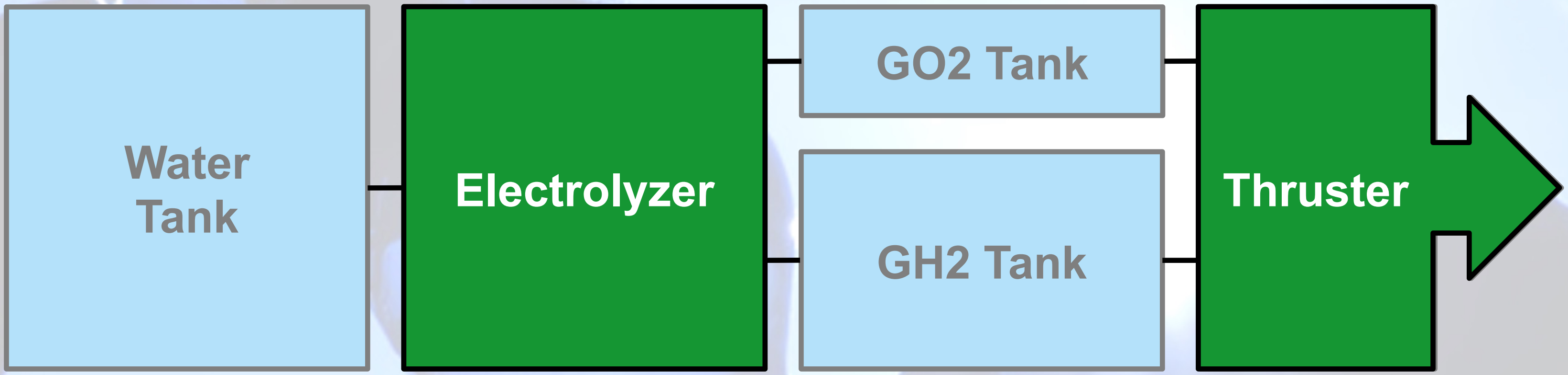
Green Propellant Properties / Technologies

Energetic Propellants cannot be harmless

Hazards	Flamable	Corrosive	Toxic	Health	Environm.	Explosive	Harmful	Oxidizing	Compress.
Hydrazine	X	X	X	X	X	(X)	X		
Ammonium Dinitramide (ADN)	X			X		X	X		
Hydroxylammonium Nitrate (HAN)			X	X	X	X	X		
Hydrogen Peroxide		X				(X)	X	X	
Nitrous Oxide						(X)	X	X	X
Water									

Still Green when the entire lifecycle is considered?

WATER PROPULSION – THE ULTIMATE GREEN

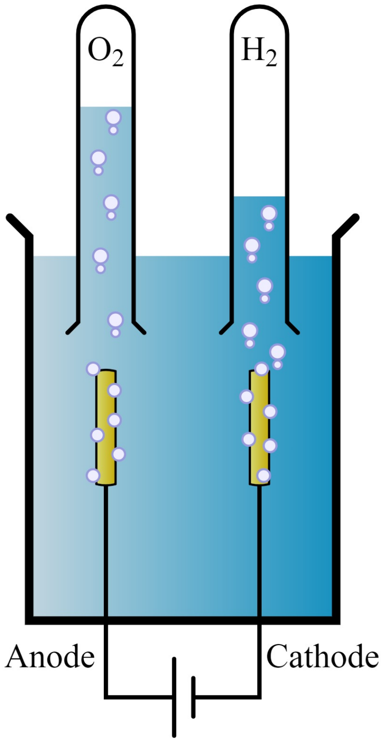


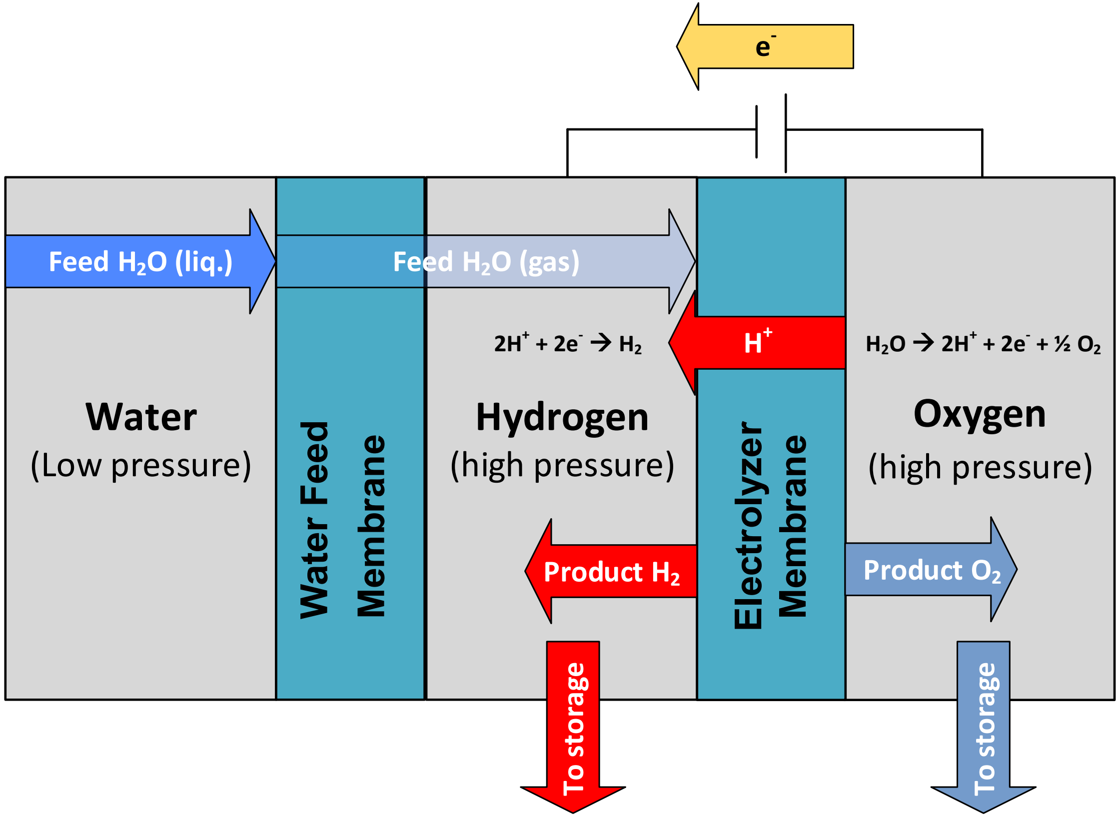
Low Pressure

High Pressure

Mixture Ratio = 8

Challenges and Solutions for the Electrolyzer





ELECTROLYZER DEVELOPMENT @ AGG

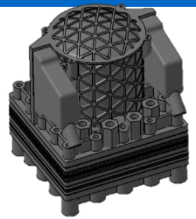
Heritage

- In house developments
- Key component
- Built and tested to gain confidence
- 100 bar operation

Lab Model

- Single Cell
- Proof of Concept
- Basic Characterisation

CubeSat EM



- 2 Cells
- Higher power
- Compact
- Integration of System Infrastructure
- 25 bar
- 10 W per cell

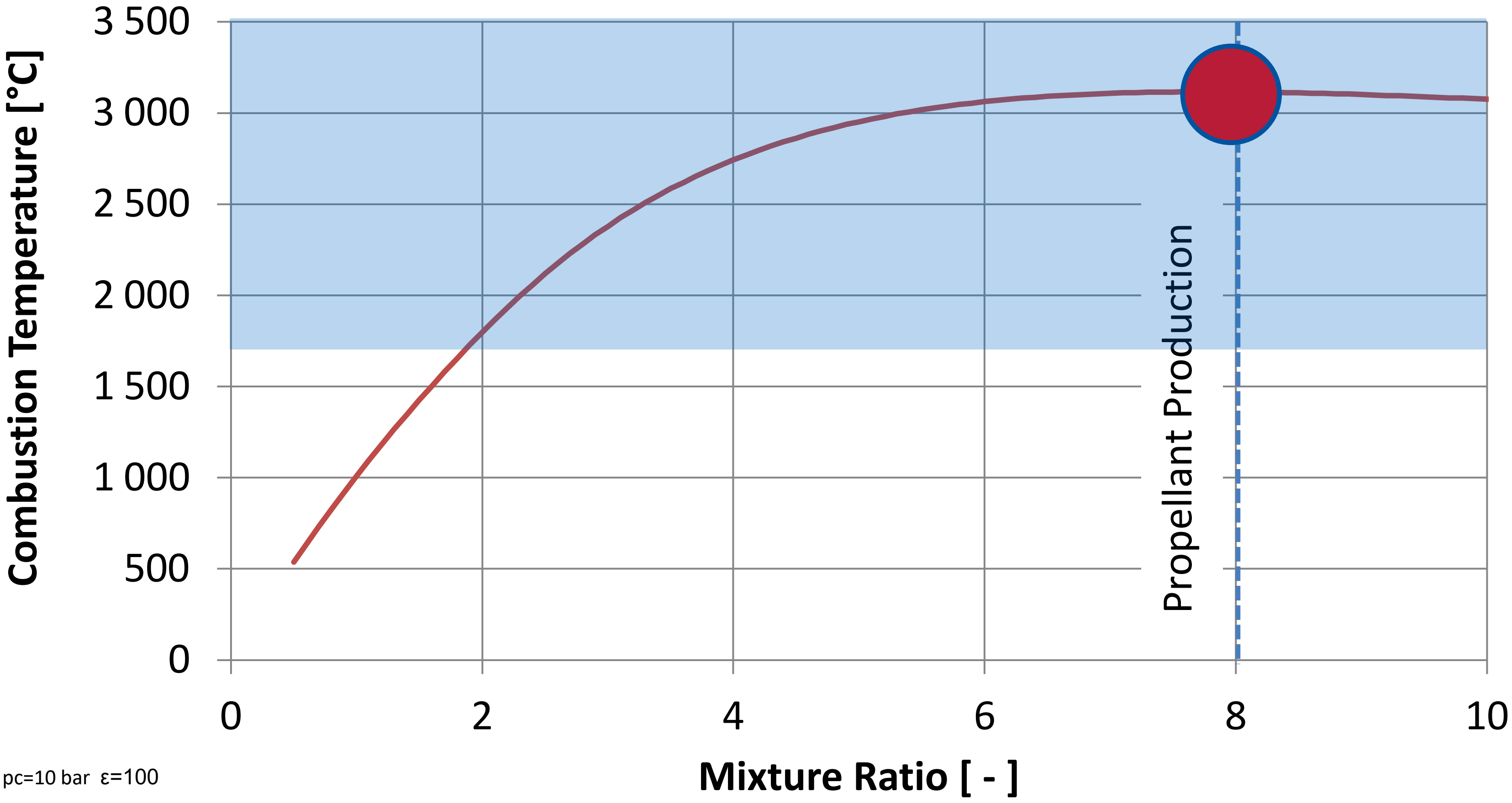
Upscale DM

- 4 Cell Design
- Higher power
- High Pressure
- 70 bar
- 35 W per cell

Flight Design

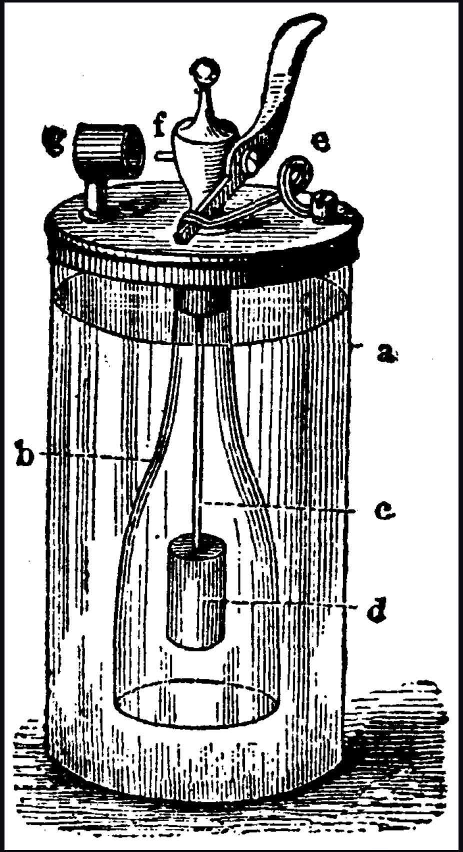
- 4 Cell Design
- Upscale for higher power
- 100 bar
- 50 W per cell

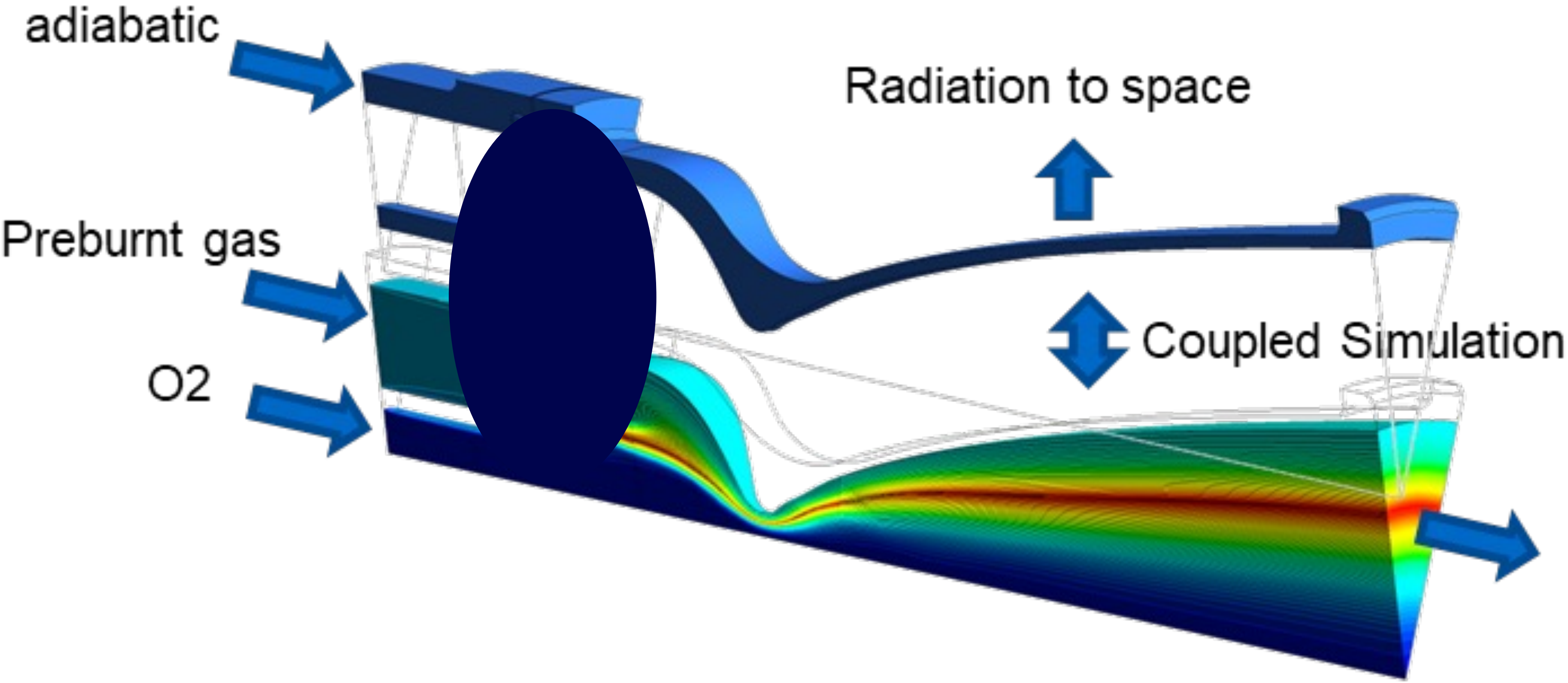
arianeGROUP

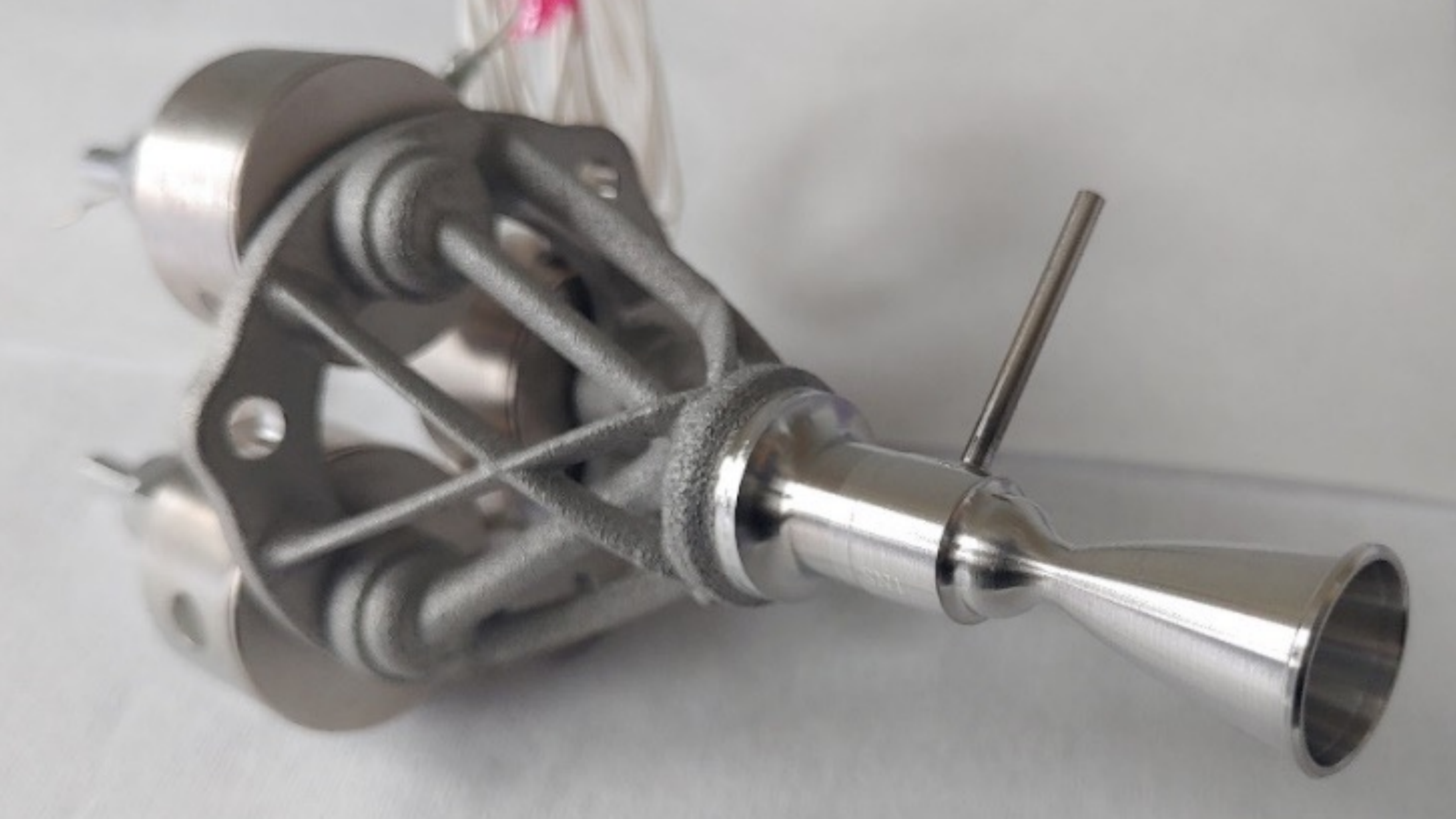


pc=10 bar ε=100

How do we ignite?



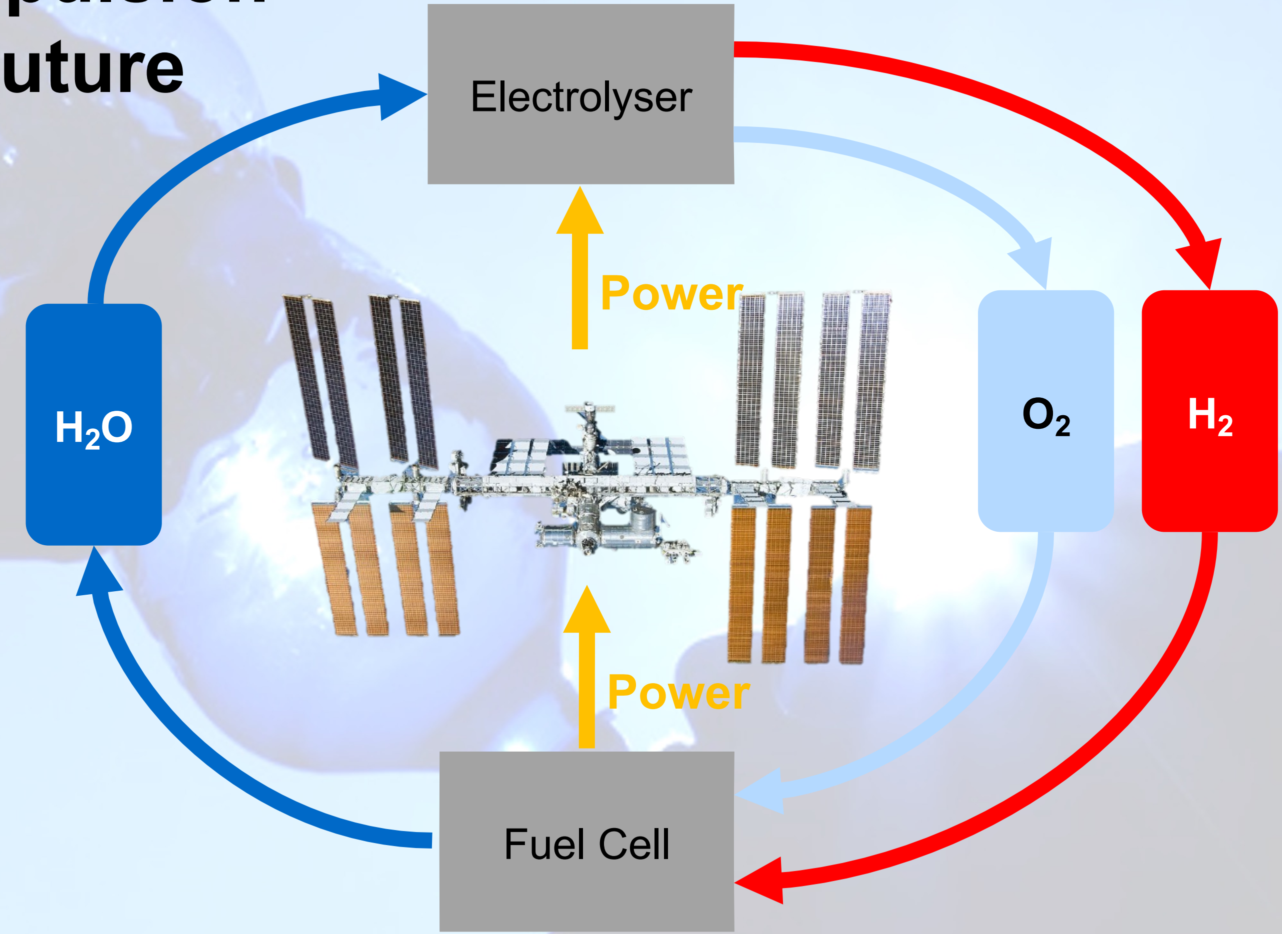

adiabatic
Preburnt gas
O2
Radiation to space
Coupled Simulation



Thruster Test Program and Results

- Variation of Cat Bed mixture ratio
- Steady state Operation from 7,5 bar to 82,5 bar in continuous and blow down mode
- Equal pressures and 5 bar pressure offset
- Pulse mode firing (MIB, ON- and OFF modulated)
- Coupled Test with Gases produced by the PEM Electrolyser
- Cold gas operation

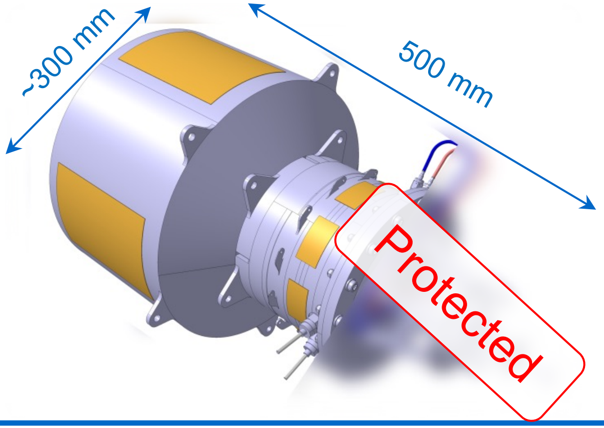
Water Propulsion – The Future

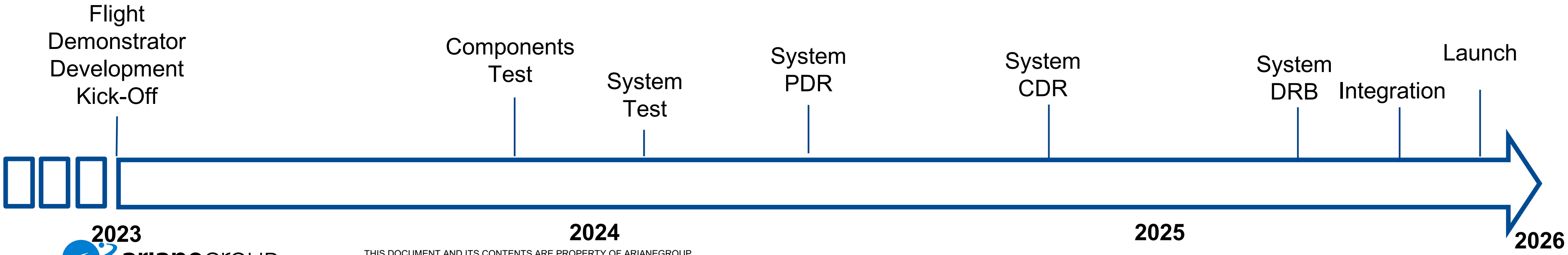


WATER PROPULSION FLIGHT DEMONSTRATION

Propulsion Pod

- Highly integrated
- Scalable and modular
- 1 or 4 thrusters
- 60 kNs of water capacity
- 250 W electrolyser
- 40 Ns manoeuvres
- 2N Thruster (ISP > 300s)
- Power and Avionics Unit





Water Propulsion

Has lower overall lifecycle cost

Allows quick turnaround times

Has a high Performance

Is environmentally friendly

THANK YOU FOR YOUR ATTENTION!

Contact: malte.wurdak@ariane.group