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Payloadproject.com

Treiber Concept

Convert fuel catalytically

Driving the chemical reaction

Patent application:

34 Pages
37 Claims
27 Figurs

Content:

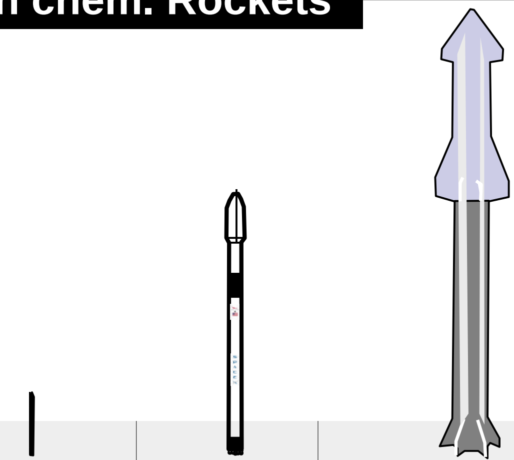
State of the art 2021 - Rocket launches from earth with chem. Rockets

economic:

→ **Radical innovations necessary to keep up the pace of development and remain competitive**

technical:

→ **Payload share still limited!**



approx. 1-4% payload for Low Earth Orbit (LEO) - low earth orbit

for smaller rockets tends to be lower

Type	Electron (Rocket Lab)	Falcon 9 (SpaceEx)	planned Starship (SpaceEx)
Propellant	LOX, RP1	LOX, RP1	LOX, Methan
Take-off mass [t]	13	541	5.000
Payload LEO [t]	0,3	23	>100
Payload LEO [%]	**2,3**	**4,2**	**ca. 2,0**
Cost [US $ million]	7	62	2
spec. cost [$/kg]	**23.333**	**2.719**	**20 (Target: complete recycling)**

➔ **Goal of Lastprojekt.de: more payload share for rockets**

Savings of up to 50% estimated

Justification by the following assumptions:

- Consumption of homogeneous catalysts approx. 100 µgcatalyst/kgfuel → 0.1 g/tfuel estimated approx. 10 €/tfuel.
- Estimate techn. homogen. Catat. large engine €1 million, medium engine €250 t, small engine €100 t.
- heterogeneous catalysts: approx. 150 t€ for small engine and approx. 300 t€ for medium engine
- Reduction of temp. by at least 500 °C → from approx. 3,000 to approx. 2,500°C, roughly approx. 1/6 (slide 8)
- Simplifying: of total power, approx. 2-30% thermal losses* (decreases with increasing engine size)*.
- Conserv. Assumpt. approx. 1/6 of >>2% for lower stage + approx. 1/6 of approx. 30% for upper stage thrust gain.

→ highly simplifying conservative at least 1% more payload share of total mass

- additionally due to reduced divergence and other effects at least approx. 1% more payload fraction
- (e.g., less chemical losses, reduced necking, etc.)

→ **Near-term target to total launch mass: approx. +2 % additional payload fraction.**

→ **ambitious long-term target: at least +10 % payload share (e.g., with advanced nozzle concepts such as aerospikes).**

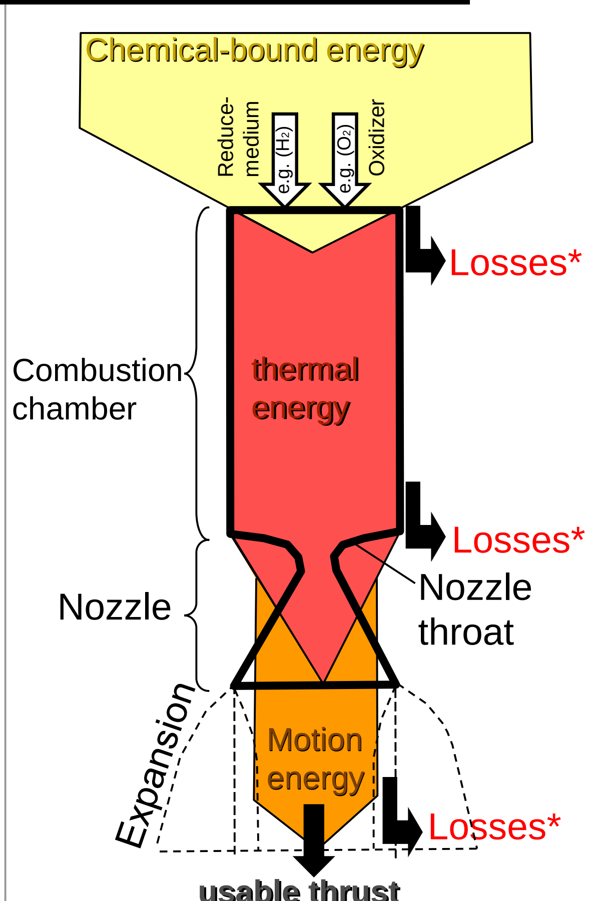
Table 1: Estimate of economic viability - conservative scenario (assuming feasibility)

System	Payload [t]	spez. Kosten [€/kg]	Catalyst homogeneous [€]	Technique cat. homogeneous [€]	Catalyst heterogeneous [€]	Spec. cost new [€/kg]
Ariane 5	20	9.500	ca. 7.000	1.250.000	ca. 3.000.000	**ca. 5.000**
RocketLab: Electron	0,3	23.333	ca. 130	200.000	ca. 300.000	**ca. 12.500**
SpaceEx: Falcon9	23	2.719	ca. 5.000	1.000.000	ca. 3.300.000	**ca. 1.500**
SpaceEx: Starship	>100	20	ca. 45.000	2.500.000	(ca. 10.200.000) (reuseable)	**ca. 11**

Multiple energy conversions

→ lossy (approx. 40-70% usable thrust[1])

Energy model / scheme



- Speed of chem. Conversion limited*

(chemical to thermal/motion energy)

- higher combustion chamber temperature ➔

higher exit velocity, but*:

- simultaneously increases: cooling, heat losses

aggressiveness of the reaction

- simultaneously decreases: Strength / service life of materials

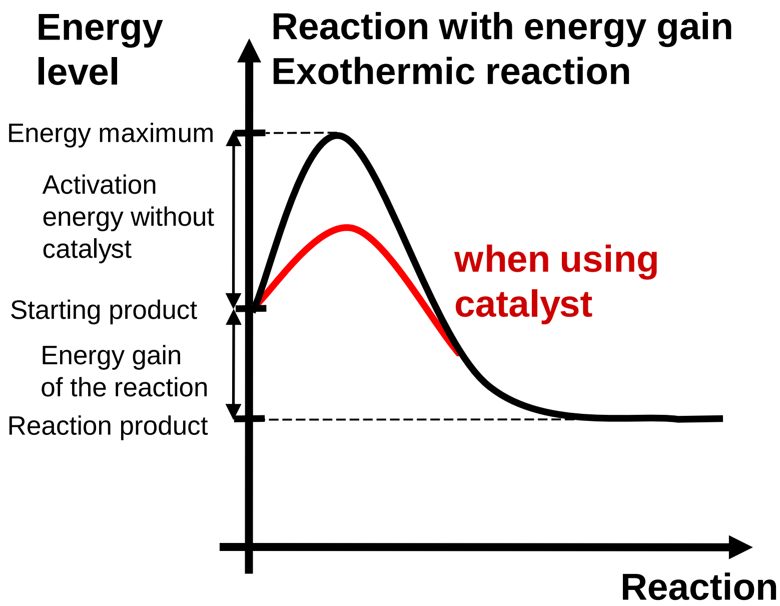
- Nozzle adapted to specific external pressure ➔ but varies with height above zero*.

[1] Source: Ernst Messerschmid et al: Raumfahrtsysteme; 4. Auflage, 2011, ISBN 978-3-642-12816-5

*** Conclusion: Alternatives to Thermo-Chemistry are advantageous**

approx. 80% of all chemical processes take place with catalyst [2].
→ increase yield and energy efficiency → economic efficiency

Energy scheme



Mode of action / effects [2]:

- Bonds of the reaction partners are dissolved
- Catalysts reduce activation energy (e.g. reactions under lower temperature)
- Catalysts can accelerate reactions / cause higher reaction rates at the same temperature ➔ "chemo-progressive".

homogeneous catalysts:
in phase with reaction product
(e.g. particles / liquid / gas in fuel)

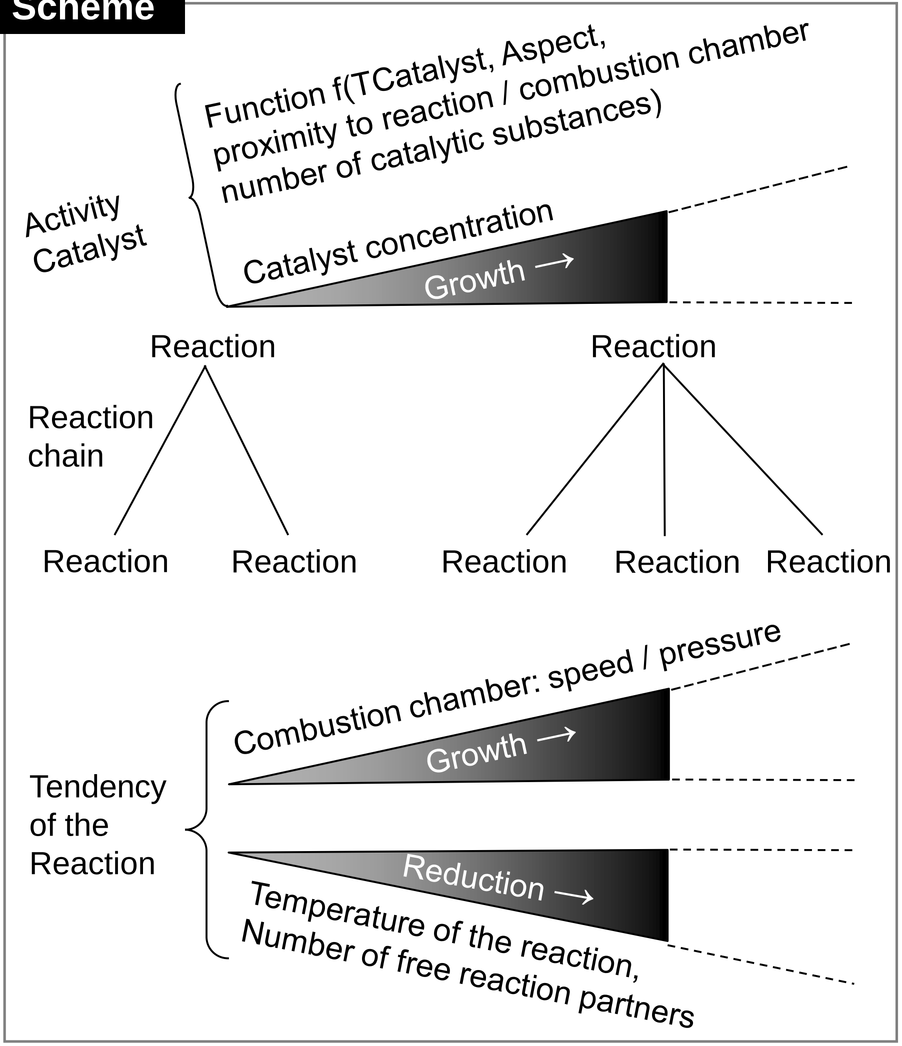
heterogeneous catalysts:
- **not in phase with reaction products (e.g. 3-way catalyst on car, separate solid)**

e.g. platinum, platinum group metals, precious metals, but also transition metals

[2] Source: Prof. Dr. Erwin Riedel et al: Anorganische Chemie, 6. Auflage (2004) TU-Berlin, Verlag de Gruyter, ISBN 3-11-0181685-1

Activity → conversion rate / effectiveness

Scheme



Major factors influencing activity:

higher application temperature = higher activity

➔ **maximum melting temperature advantageous**

if necessary targeted excitation with electromagnetism

the higher / finer the surface - the greater the activity

if necessary increase by promoters / stabilizers

(e.g. rhenium counteracts coking)

homogeneous catalysts for reactivation of heterogeneous

➔ catalysts

(against fouling / residues on surface)

Use in combustion chamber advantageous to achieve __highest activity possible

at high activity very economical:

for homogeneous catalysts: often millionths (mg/kg) or billionths parts (µg/kg) in fuel are sufficient

For heterogeneous catalysts, layer thicknesses <1 µm are already sufficient in some cases

therefore also the use of precious metals is very useful (e.g. platinum, PGMs or gold)

➔ e.g. motor vehicle consumption reduced by 12 to 48 (patent specification DE 600 16 706 T2)

➔ **homogeneous catalyst only approx. 0.01 € / l fuel at 1,5 € / lfuel -> up to 0,71 € / lfuel saving**

➔ **in space travel potential higher - less mass**

Catalysts act directly and indirectly

technical effect with arrow→

Direct effects (bracket expressions freely chosen):

Earlier start of the reaction ("inito-chemical").
→ lowering of the activation energy /
Stronger branching of the chain reaction
→ Lowering of the reaction temperature
(less external heat loss)

Acceleration of the reaction ("chemo-progressive")
→ higher exit velocity**, more speed of the engine possible**

Completion of the reaction ("potentio-chemical")
→ burnout / reaction of the reaction partners is increased (especially for air-breathing engines).

Indirect effects (e.g.):

→targeted adaptation combustion chamber geometry (less constriction)

→ **adaptation outlet pressure to ambient pressure Due to intermediate change in concentration (reduction of kinematic jet losses).**

→ Removal of residues / fouling in combustion chamber for longer service life of the materials

→ Uniformity of the reaction /
increase of the service life of the material**s**

→ **by reducing the consumption, less fuel / oxidizer needs to be co-accelerated**

→ Reduction of unwanted dissociation at the end of the Combustion chamber "thermolysis" (internal heat losses are reduced)

→ Effects / impact pathways with great potential

Comparison with / without catalyst*

*(Le Chatelier: reaction depends on pressure and substance proportions)

Reaction	$H_2 + \frac{1}{2}O \rightarrow H_20$ without catalyst	$H_2 + \frac{1}{2}O \rightarrow H_20$ with catalyst
Example of use	autogenous welding	Chem. oxyhydrogen test
Temperature [°C]	> 2.000 °C [1]	> 600°C* [2]
Speed	continuous (pressure can escape)	explosive (pressure is built up)

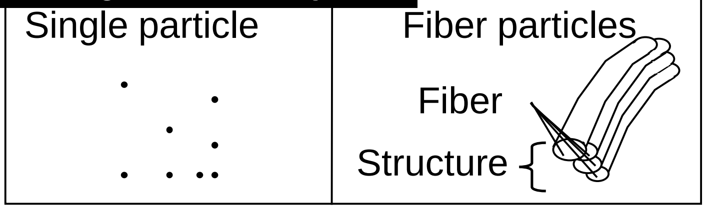
→ **Conclusion: approx. 1,000°C temperature difference is technically possible [3].**
(depending on reaction conditions and reaction partners also e.g. only approx. 200°C).
Conservative assumption for more realistic near-term goal: 500 °C temperature difference.

Sources:

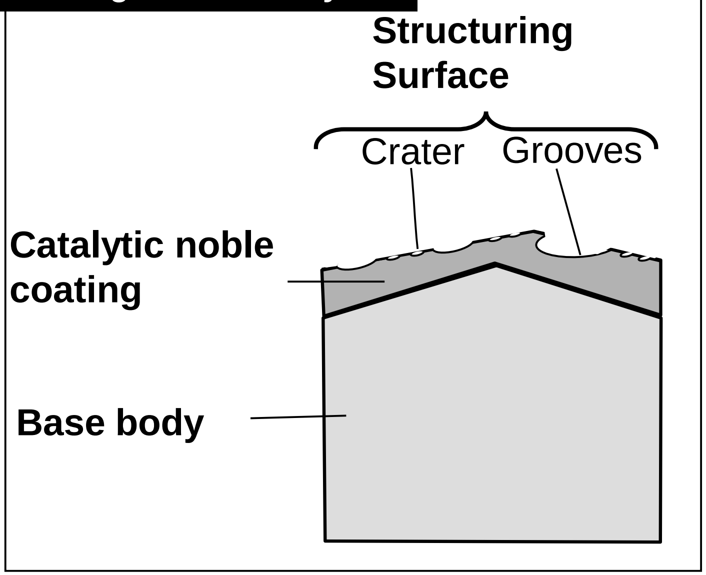
[1] www.chemgapedia.de/vsengine/glossary/de/autogenes_00032schwei_00223en.glos.html
[2] www.chemgapedia.de/vsengine/glossary/de/knallgas_00045reaktion.glos.html
[3] Xiafeng Yan (Dissertation): Numerische Simulation und Zeitskalenanalyse…

Selection of temperature-resistant materials

Homogeneous catalysts



Heterogeneous catalysts



Material Particle or Coating:

Material / Alloy	**Melting point***
80% Platinum - 20% Tungsten	ca. 2.000 °C
70% Platinum - 30% Rhodium	ca. 1.800 °C
55% Platinum - 45% Rhenium	**ca. 2.400 °C**
50% Platin. - 50% Molybdenum	ca. 2.000 °C
25% Platinum - 75% Tungsten	ca. 2.460 °C
25% Platinum - 30% Osmium - 45% Iridium	ca. 2.400 °C
80% Osmium - 20% Iridium	ca. 2.800 °C
50% Osmium - 50% Iridium	ca. 2.600 °C
42% Iridium 33 % Rhenium 25 % Rhodium	ca. 2.700 °C
Tungsten	ca. 3.410 °C
Molybdenum	**ca. 2.617 °C**

Material Base body: Tungsten, Molybdenum

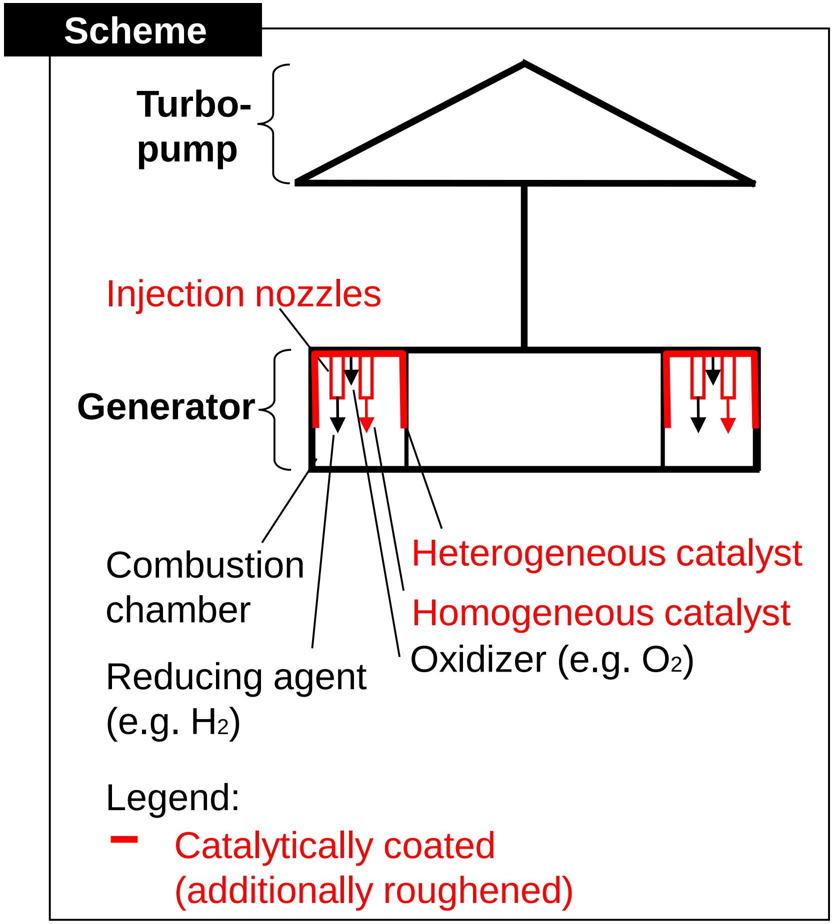
* Pressure-dependent (principle of Le Chatelier)

at combustion chamber head / catalyst significantly below combustion temp. (ca. 2.500° C)

+ further increase resistance through reactive cooling on catalyst bodies.

→ Catalyst with maximum activity / operational reliability

Turbopump: Supply of the engine



<u>Effects due to the use of catalysts:</u>

→ Uniformity of the reaction

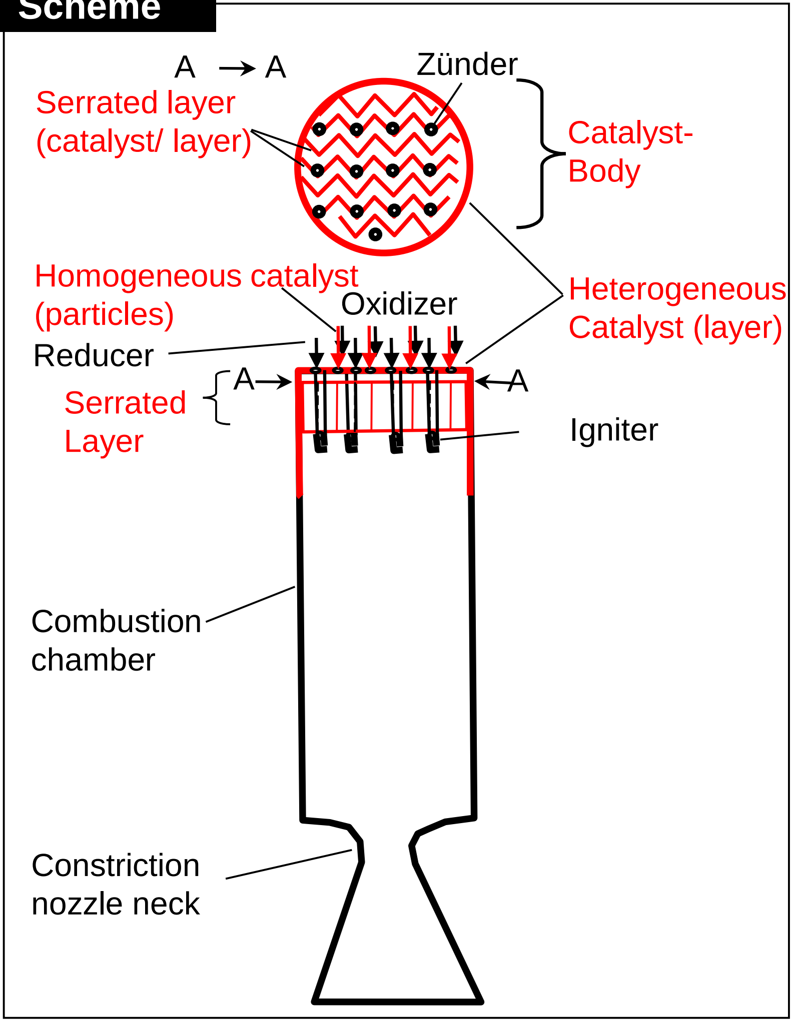
→ increase of the reaction rate
and / or
→ Reduction of the temperature in combustion chamber

→ Higher strength and service life of materials and bearings are possible
and / or
→ Increase in power output (i.e. pressure/pump rate).

→ **Ideal case: "fatigue strength" without cooling**

Bell nozzle + area type catalyst

Scheme



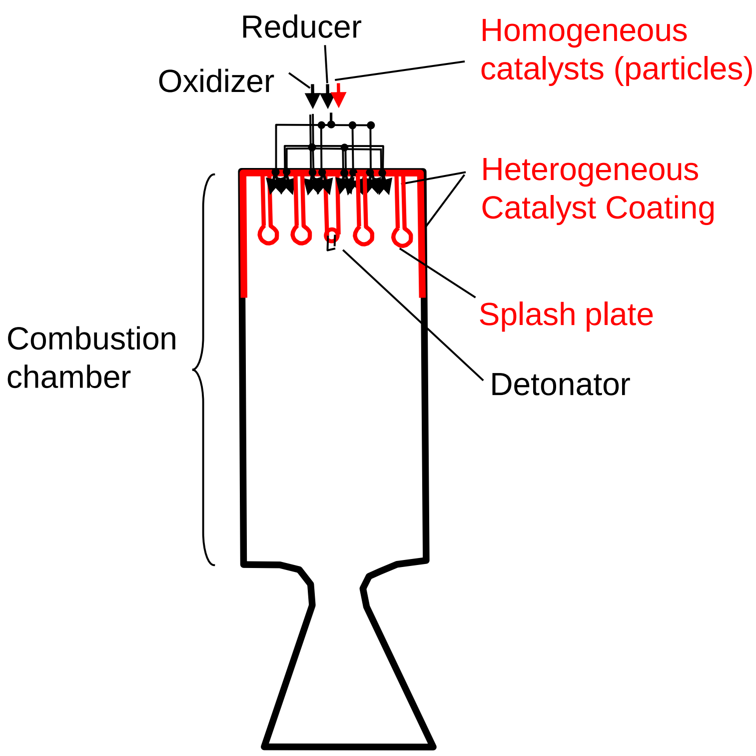
Features:

- Large surface area of catalyst body
  ➔ More efficiency.
- More catalytic material
  → better temperature distribution
- Flow in combustion chamber more axial
- Target: early dissociation
  (high dissociation at the beginning and low dissociation at the end of the combustion chamber) - less heat losses.
- **Kinematic jet losses can amount to 25% of the power expended by the engine**
- **if necessary, reduction by adjusting the freight rate of homogeneous catalysts**

Bell nozzle + linear catalyst

Scheme

Design example catalytic spray plate



Properties:

- smaller surface of the catalyst body (less material)
- more targeted inflow (partly radial)
- concentration on catalytic centers with higher temperature and activity
- lower catalytic base potential
- **kinematic jet losses can amount to 25% of the applied power of the engine**
- **if necessary, reduction by adjustment of freight rate of homogeneous catalysts**

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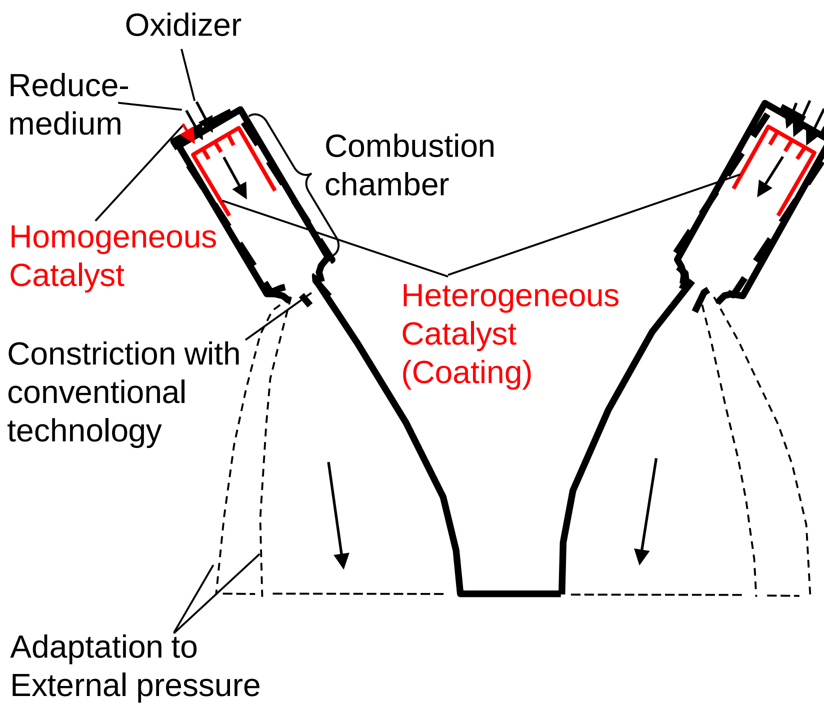
advanced nozzle concept with free relaxation

Scheme



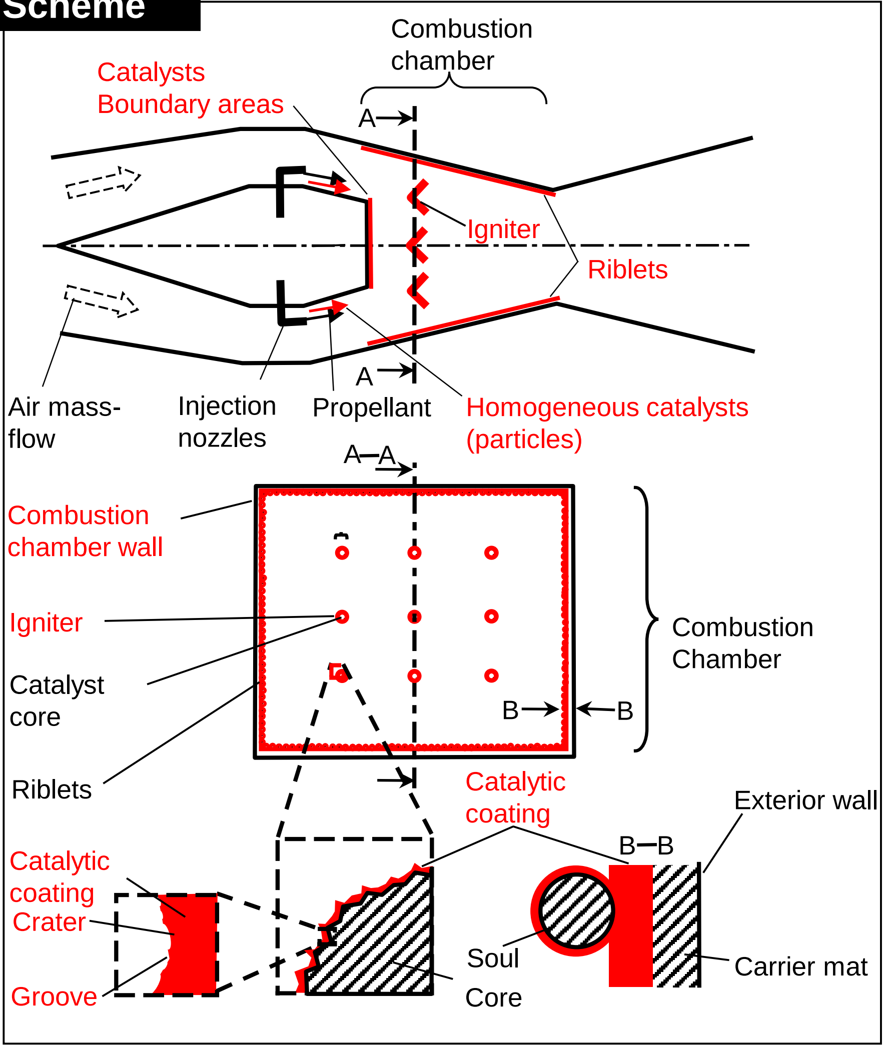
Goal: Avoidance of kinematic jet losses (e.g. in the case of bell nozzles, these can amount to approx. **25 % of the power expended by the chemical engine** / propellant). Engine / propellant

Properties:

- Aerospikes reduce kinematic jet losses (partly 25%!) - Adaptation of outlet pressure to external pressure
- due to reduced area of constriction, high thermal loads ➔ not feasible so far
➔ significantly improved heat balance
- due to reduction of the combustion chamber temperature and adaptation of the necking particularly interesting and promising
- Alternatively also tubular or conical combustion chamber (see patent specification)

Increase the burnout

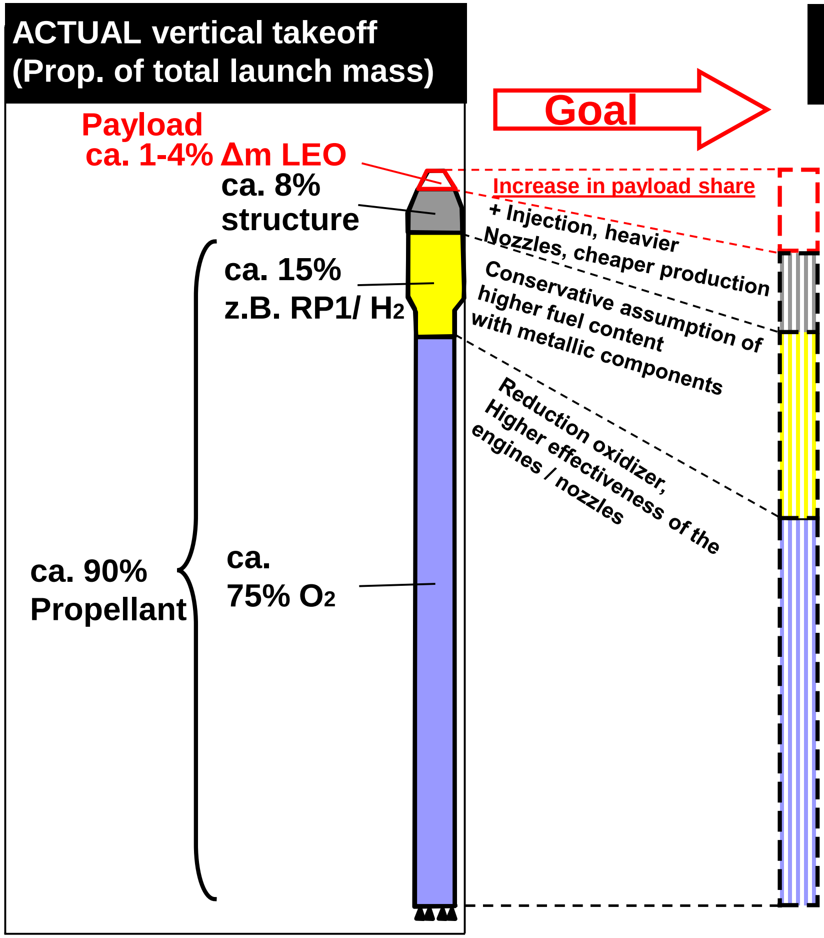
Scheme



Features:

- Large surface area due to coated combustion chamber wall, riblets and igniter.
- Reduction of fuel consumption due to more complete reaction
- Reduction of combustion temperature facilitates cooling and material selection

Summary: less energetic losses + lower-loss conversion of chemical energy into kinetic energy



Advantages:

- Accelerated reaction at reduced temperature
- equalization of the reaction
- air-breathing drives with higher burnout and simplified cooling
- Adaptation combustion chamber possible

→ **higher net thrust**