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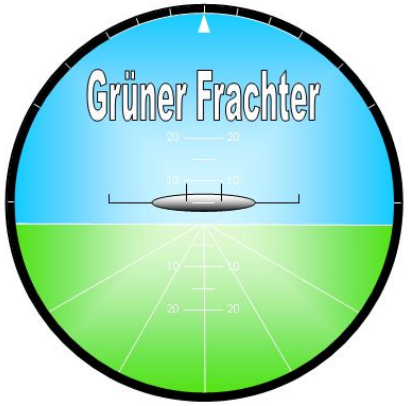

Auslegung des Kraftstoffsystems von wasserstoffbetriebenen Frachtflugzeugen

Sevgi Batal

HAW Hamburg

Bishop GmbH – Aeronautical Engineers

Hamburg, 19. Juli 2010

Content

Alternative Fuel Hydrogen

LH_2 is best per unit weight but it isn‘t per unit Volume

- heavy cryogenic fuel tank
- increase OEW some 13%,
  but MTOW is about 5% lighter
- Will need 28% more energy on 500NM mission,
  on 3000NM mission the lightweight properties start to overcome, aircraft will only use 2% more energy
- Equal-zero-emission: NOx and H_2O
  NOx is depending on pressure, temperature, dwell time in burning zone – Hydrogen allowed lean, low temperature combustion and the high rate of combustion is leading short dwell times

Effects of Water on Atmosphere

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Greenhouse effect of water vapor is depending on altitude

- 3-4 days at ground level, 8-9 days in Troposphere
  up to 0,5-1 year in Stratosphere
- Below 10km the contribution is negligible, above 10km becomes effective and dominates beyond 12km

➢ Flight altitude have to reduce to avoid contrails, with the result that higher fuel comsumption intend higher operating costs (only 2%)

Hydrogen Fuel System

- **Tanks**
  aerodynamic geometry, smallest possible surface because of heat input and weight
- **Valves**
  For fuelling, transport to engine, protection of tanks
- **Pumps**
  Radial pumps to transport from tank to engine, jet pumps for transporting inside the tanks
- **Pipes**
  Including connecting elements, expansion compensator and insulations
- **Gas Outlet Valve**
  In exceptinal case is needed for flow of GH2 without backflow
- **Refuel Coupling**
  For refuel cryogenic fuel
- **Sensor- and Monitoring System**
  Give you information about the normal course of operating, security-relvant datas are Controlling permanent and automatic

LH_2- Fuel System – TU155

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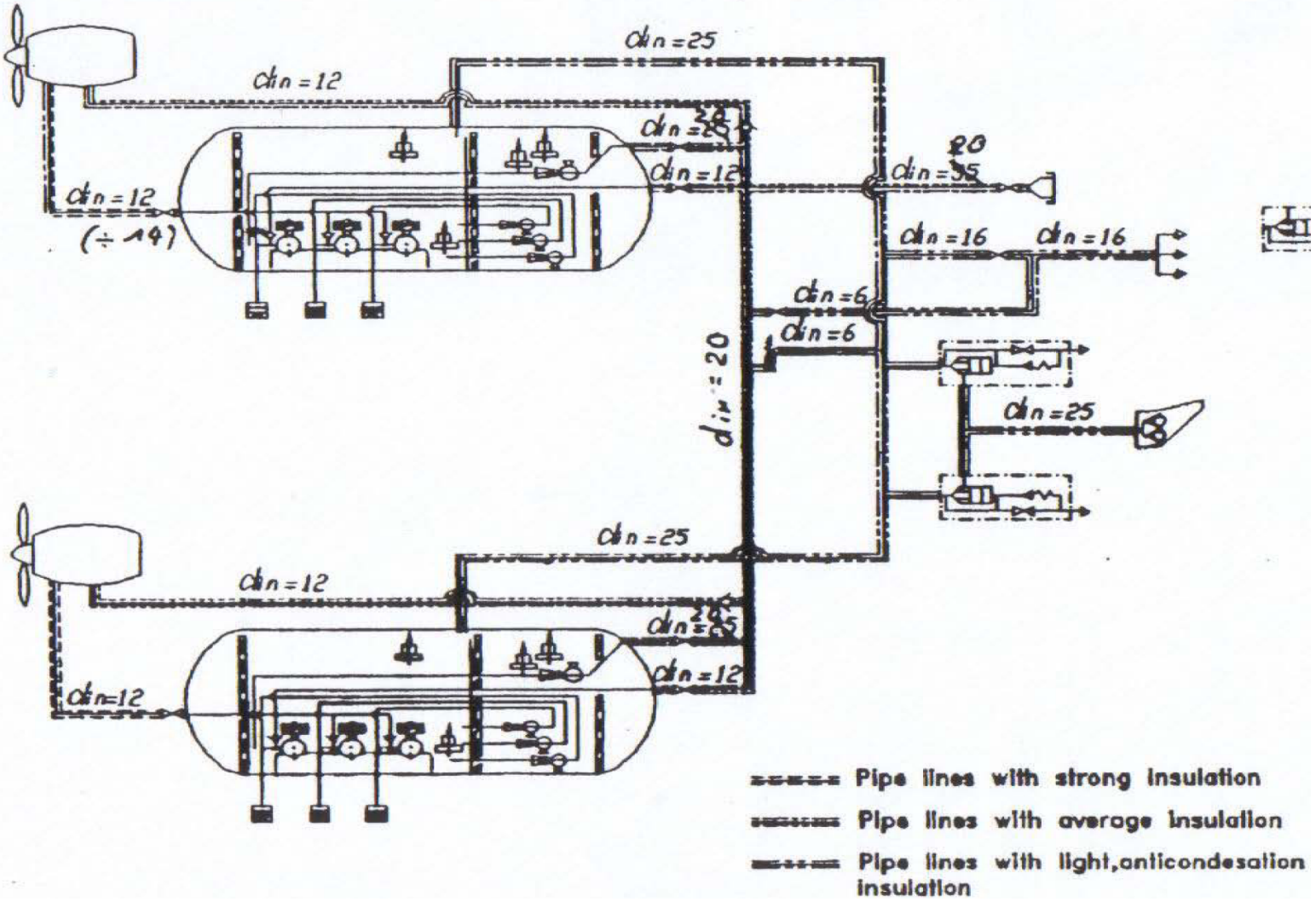

LH_2- Fuel System – DO328

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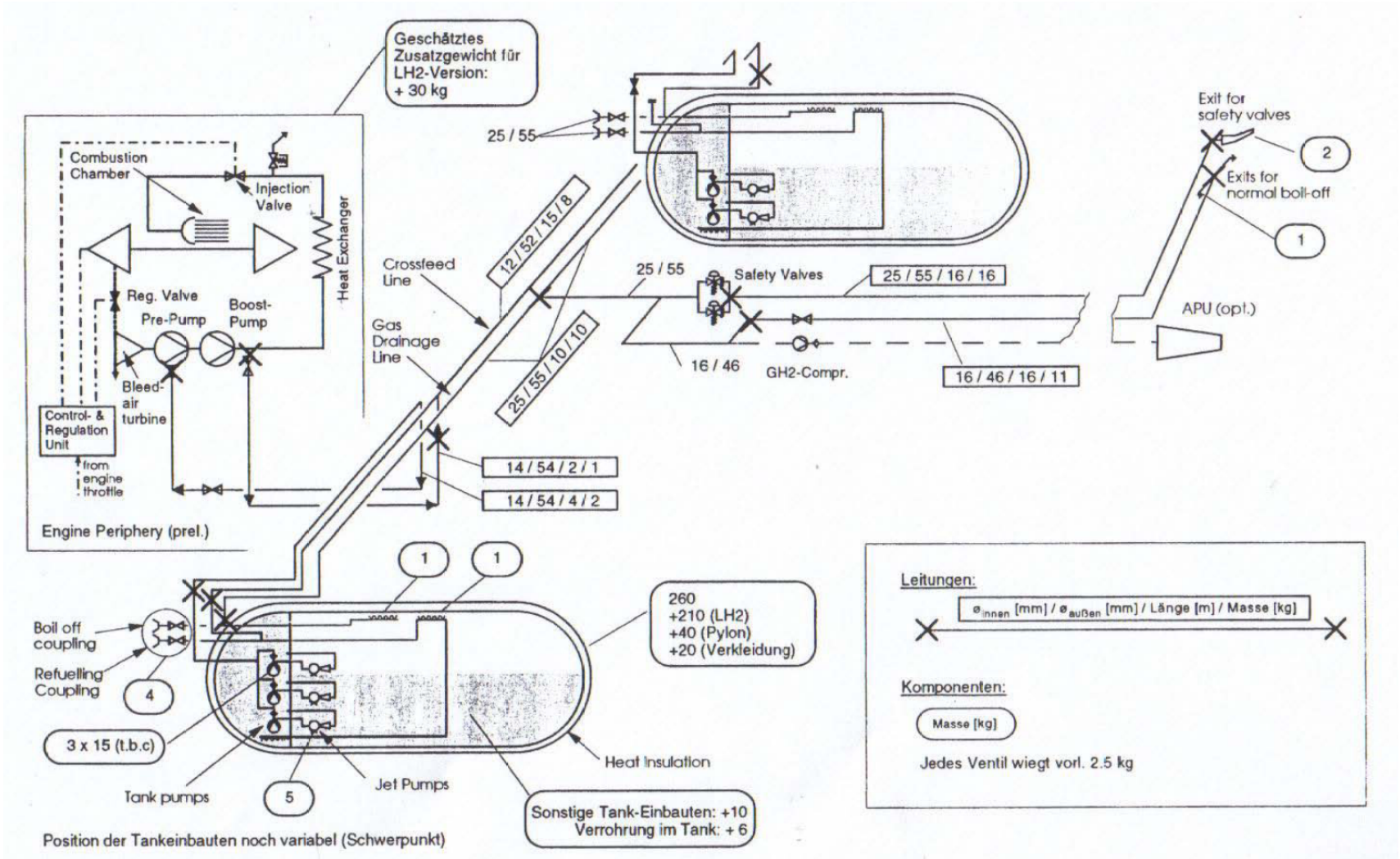

LH_2- Fuel System – A310

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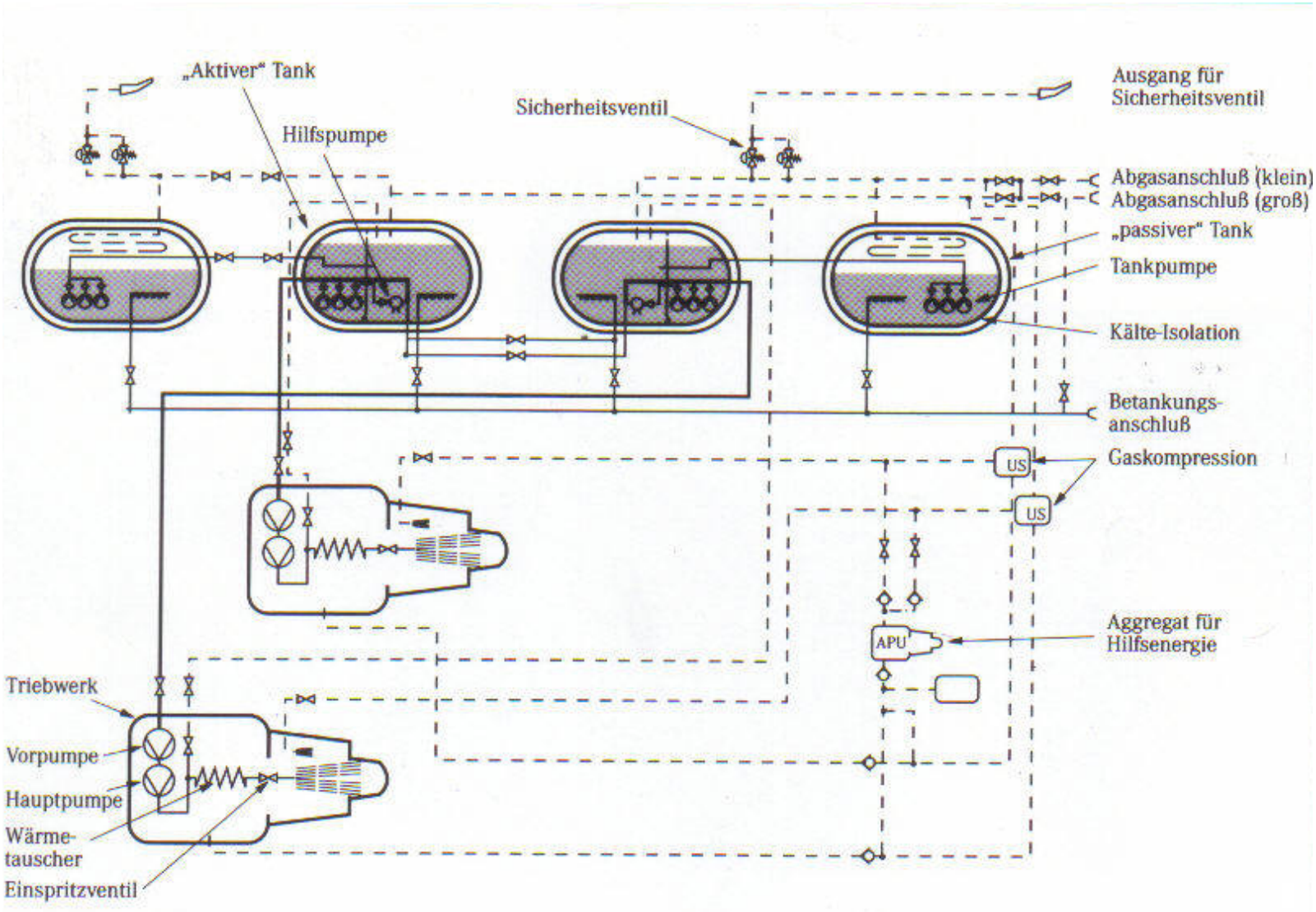

LH_2- Fuel System – A310 (EU)

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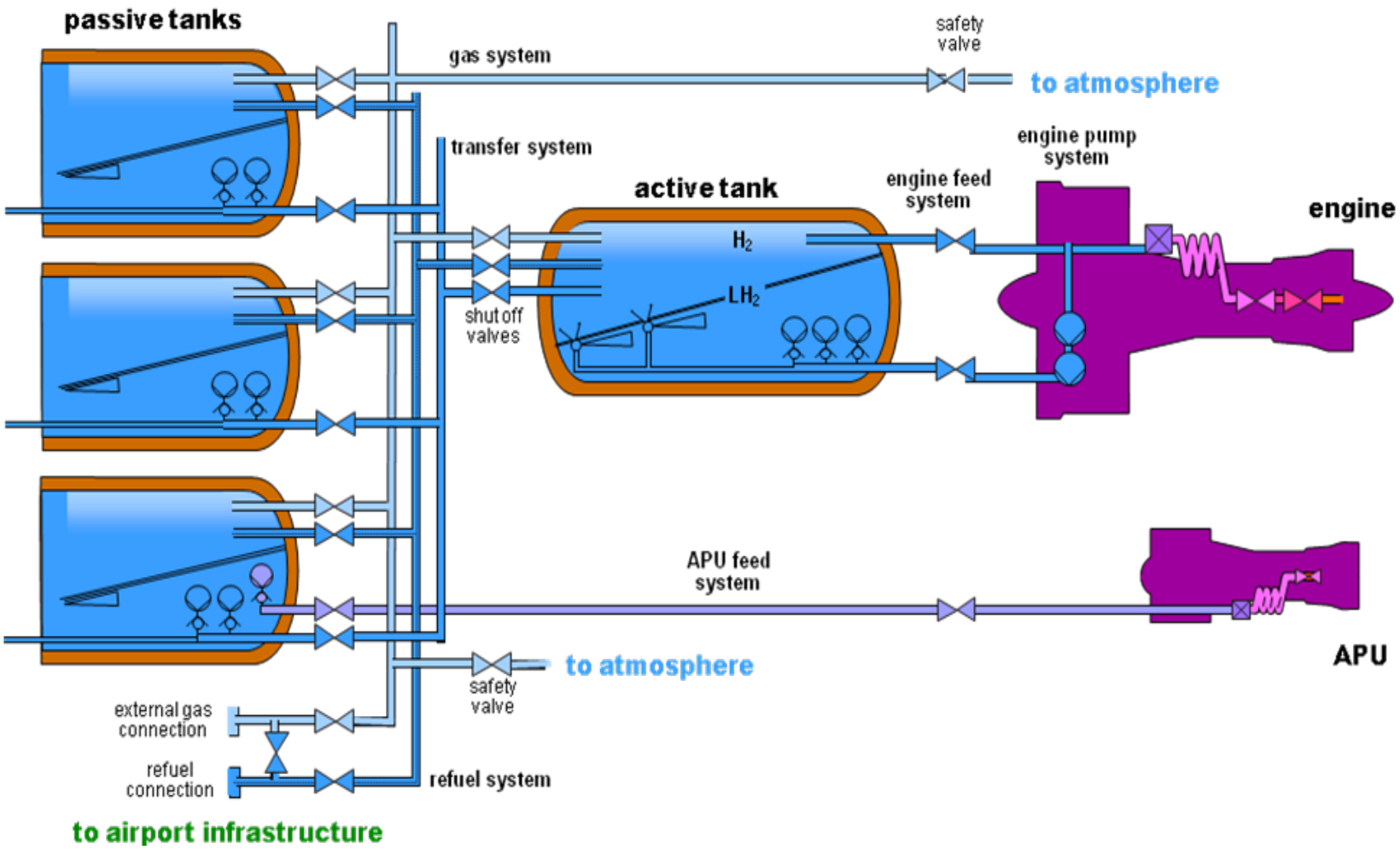

ATR-72 PrADO-Design

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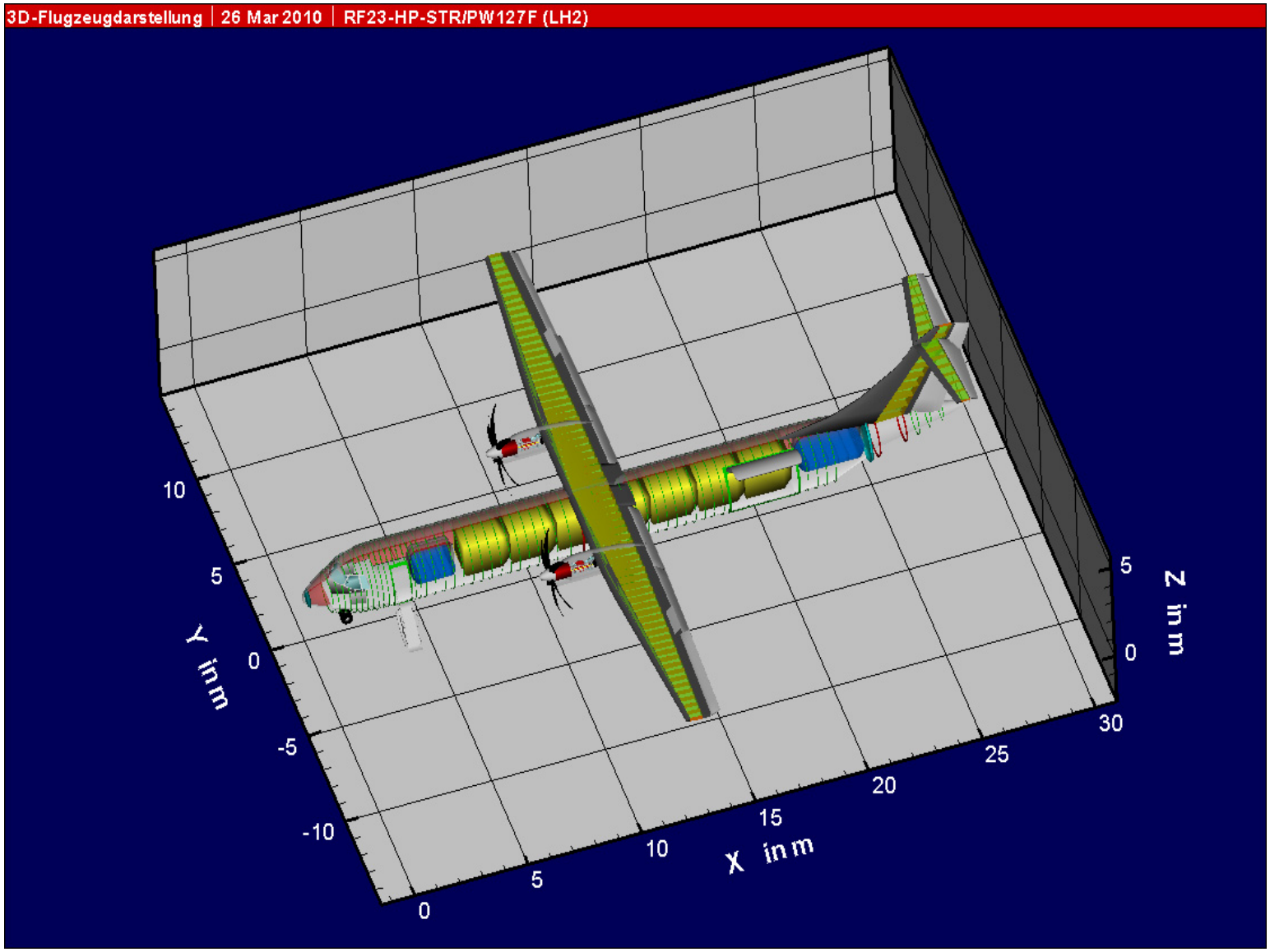

Functional Design – ATR 72

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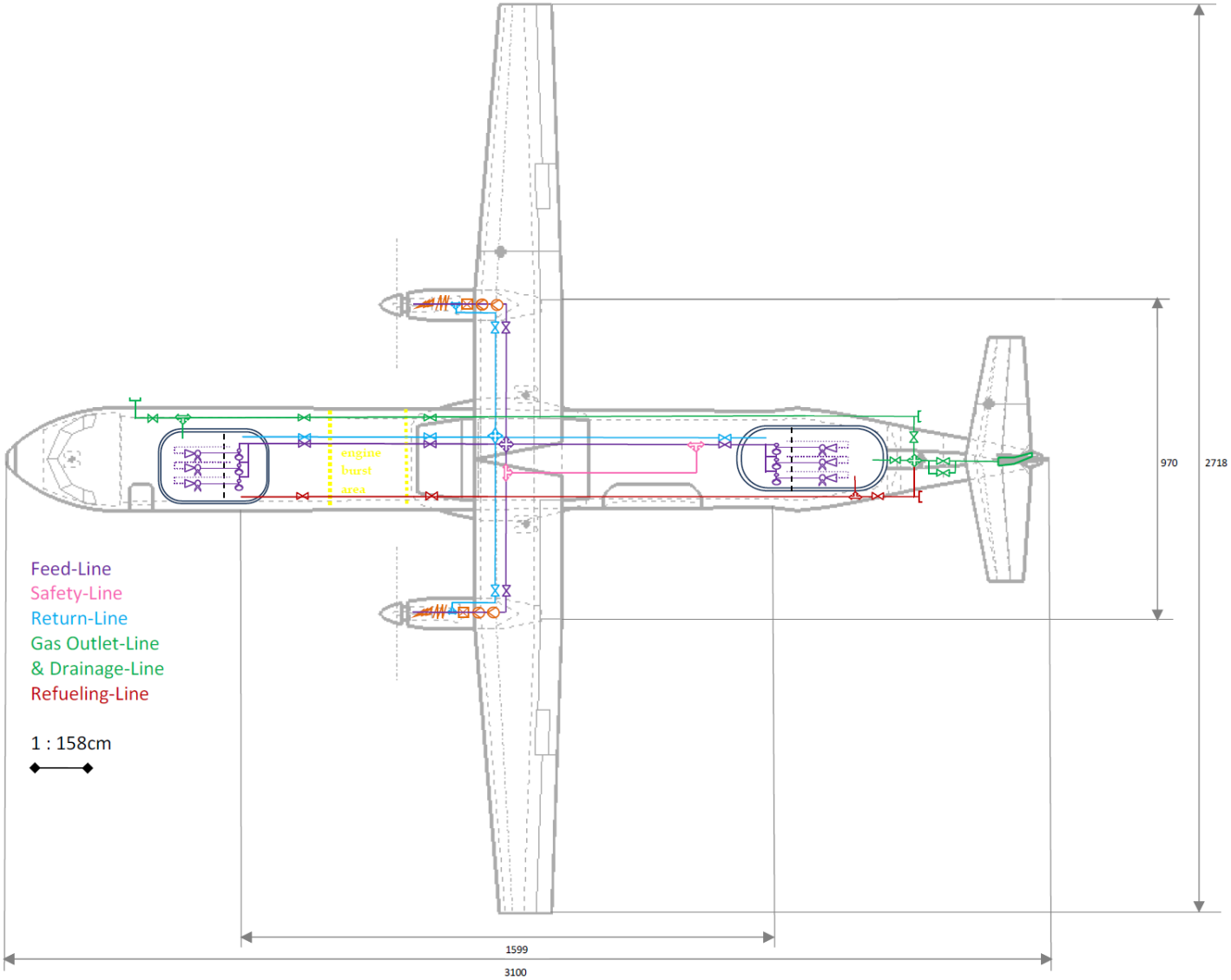

Functional Principle – ATR 72

- 2 active tanks (1 Tank feed 1 engine)
- Jetpumps deliver the fuel to the centrifugal pumps wherefrom it arrives the pressure pumps
- The two-phase-hydrogen-mixture goes to the combustor after pass a heat exchanger
- Overspill of GH2 can be traced back
- Safety valves shall be help to interrupt the fuel flow if necessary (because of the rotor burst area you need more valves)

Remodelling BWB-PrADO-Design

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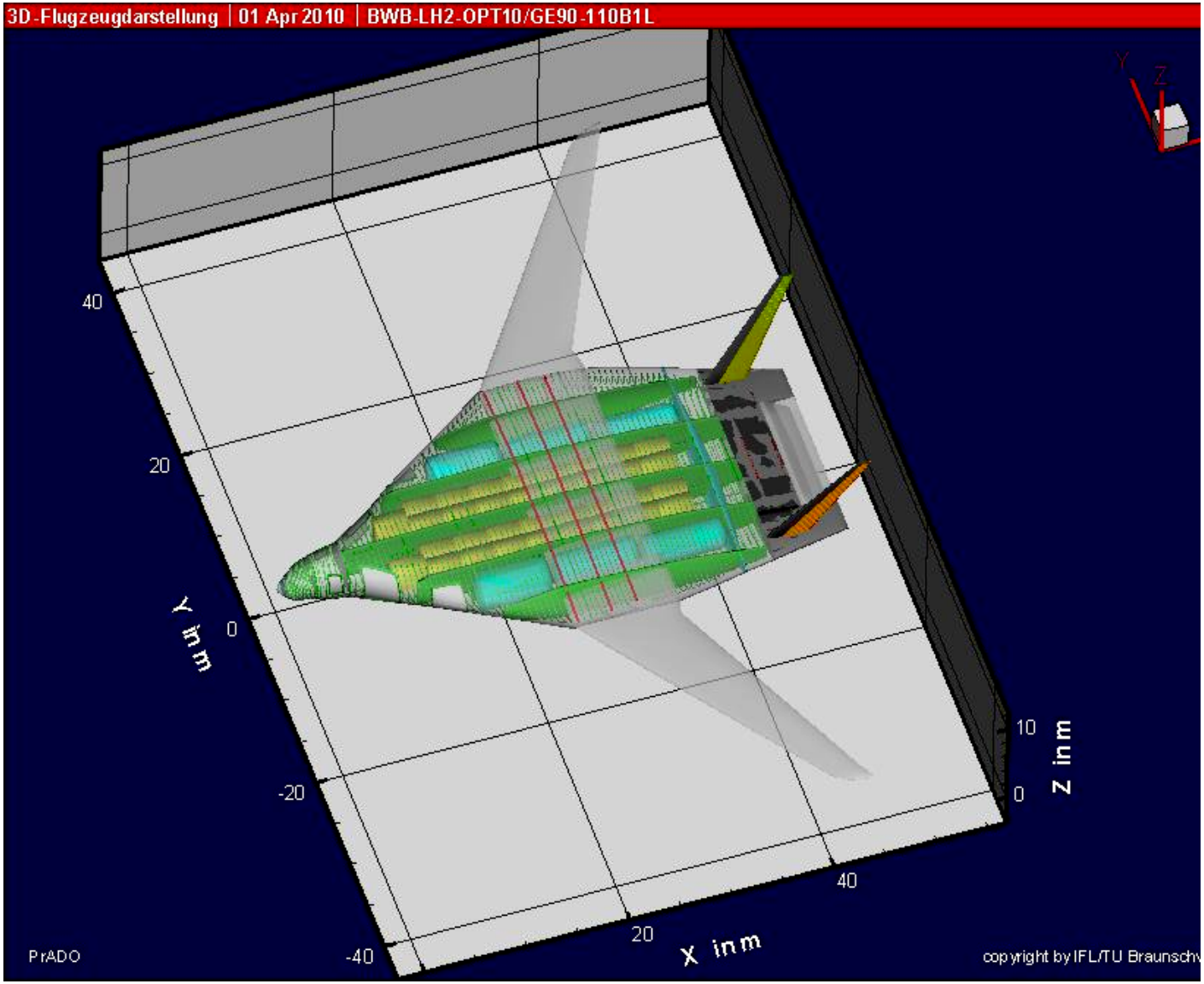

Functinal Design - BWB

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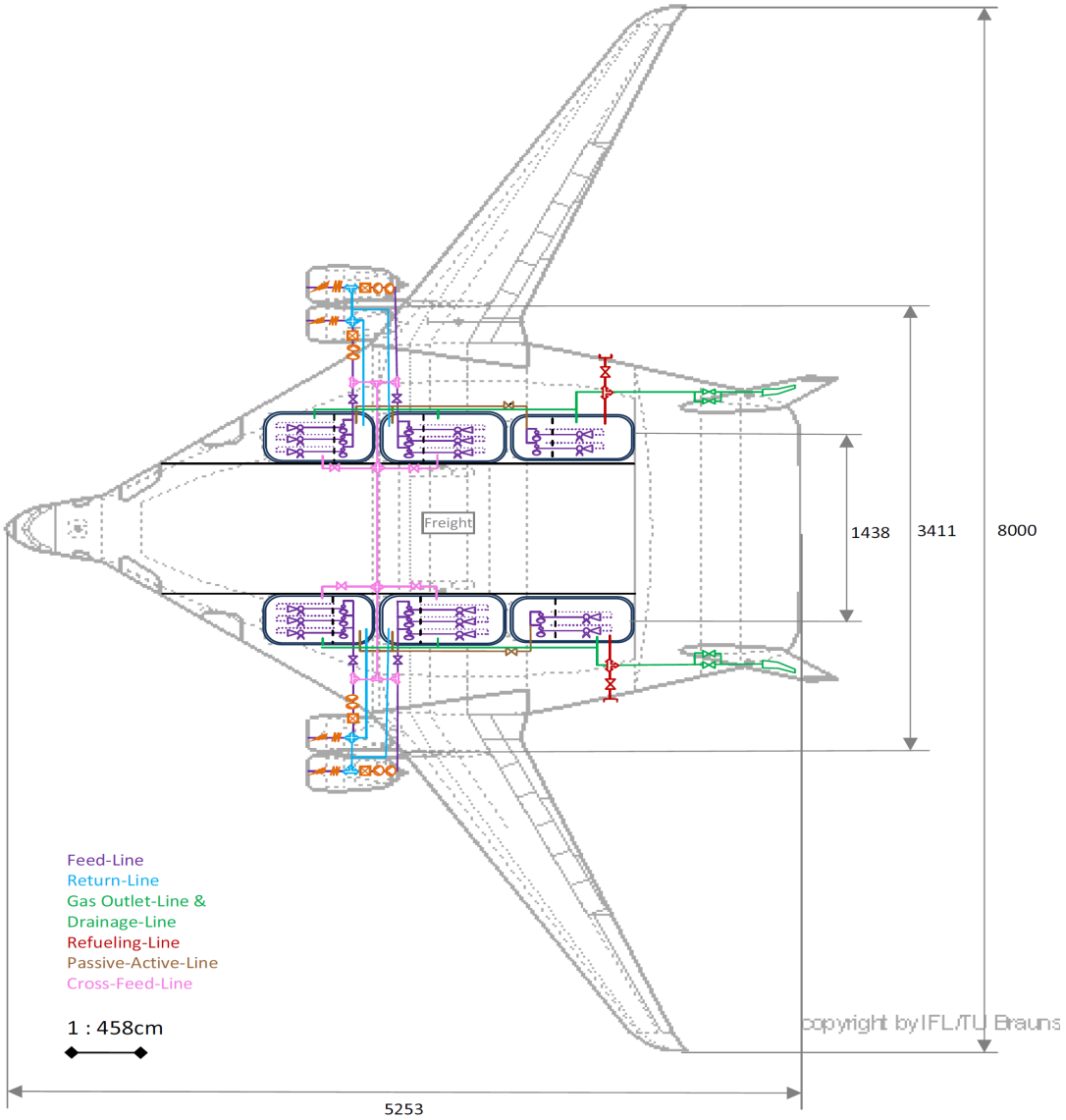

Functional Principle – BWB

- **4 active and 2 passive tanks**

  (1 tank for 1 engine and the other 2 tanks feed the aktive tanks if necessary)

- **Active tank: 3 jetpumps deliver the fuel to the 3 centrifugal pumps wherefrom it arrives the pressure pumps**

- **Passive tank: 2 jetpumps to 2 centrifugal pumps**

  and as needed to the active tanks (e.g. by falling fuel portion or damaged active tank)

- **In contrast to ATR we have a complicated cross-feed-line because of the number of tanks**

Comparison relative to components

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	ATR-72			BWB		
Components	**Single Weight [kg]**	**Number**	**∑ Weight [kg]**	**Single Weight [kg]**	**Number**	**∑ Weight [kg]**
Tank Mineralfaser (LTH)		2	574,2		6	8342,4
~~Tank Mineralfaser (Cryoplane)~~		~~2~~	~~1483,2~~		~~6~~	~~47345~~
~~Tank Mineralfaser (Luger)~~		~~2~~	~~208,8~~		~~6~~	~~3033,6~~
Radial pump	15	6	90	30	16	480
Jet pump	5	6	30	10	16	160
Piping in tank	6	2	12	10	6	60
Other interneals in tank	7	2	14	12	6	72
Refueling coupling	4	1	4	4	2	8
Pipes (Vgl. Tabelle 4.4)			**57,3**			**145,4**
Safty valves	2,5	20	50	3	16	48
Manifold valves	4	9	36	5	14	70
Sensors			40			80
Engine	650	2	1300	2400	4	9600
Heat exchanger				33,2	4	132,8
Delivery pump	30	2	60	15	4	60
Boost pump				11,4	4	45,6
Safety measures	5	2	10	5	4	20
Gas outlet (large)	2	1	2	4	2	8
Auslassventil (small)	1	2	2	2	2	4
Totalkg]			**2281**			**19336**
Total with Engine[kg]			981			9736
Tatal withot Engine Including LH_2 [kg]			**1790**			**40036**

Summary

- Standard safety rules doesn‘t still exist
- Flight altitude may have to be reduced to avoid contrails
- Nearly the same system components like conventional aircraft. Only for controlling the Temperatur you need more security relevant systems and datas
- New innovative and lightweigt materials is necessary for the system components to used crogenic liquid
- LH2-BWB with only 6 tanks are better because of heat emission

Questions

Thank you for your time

Contact persons

- Petel Luger, Astrium Space Transportation (System Analysis)
- Franz Grafwallner, ET Energie Technologie
  (Buisiness Maneger)
- Heiko Walter, ET Energie Technologie/Airbus GmbH (Fuel Cell)
- Bernd Kaufmann, Adam Opel GmbH (Manager FCA Workshops, TestLabs, Vehicle Build, Hydrogen Infrastructure & Engineering Support)
- Dirk Breuer, Toyota Deutschland (Pressesprecher Technik)