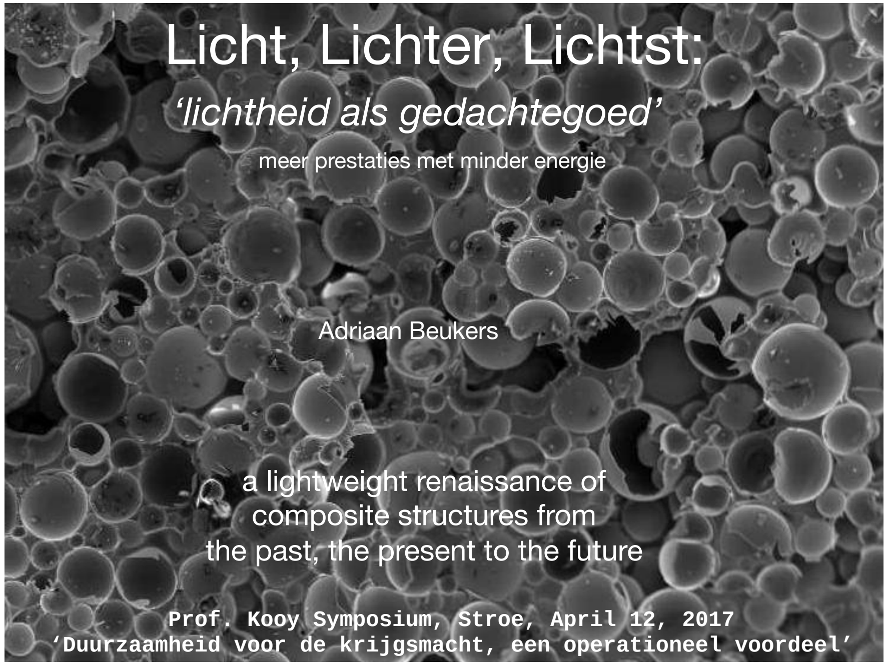
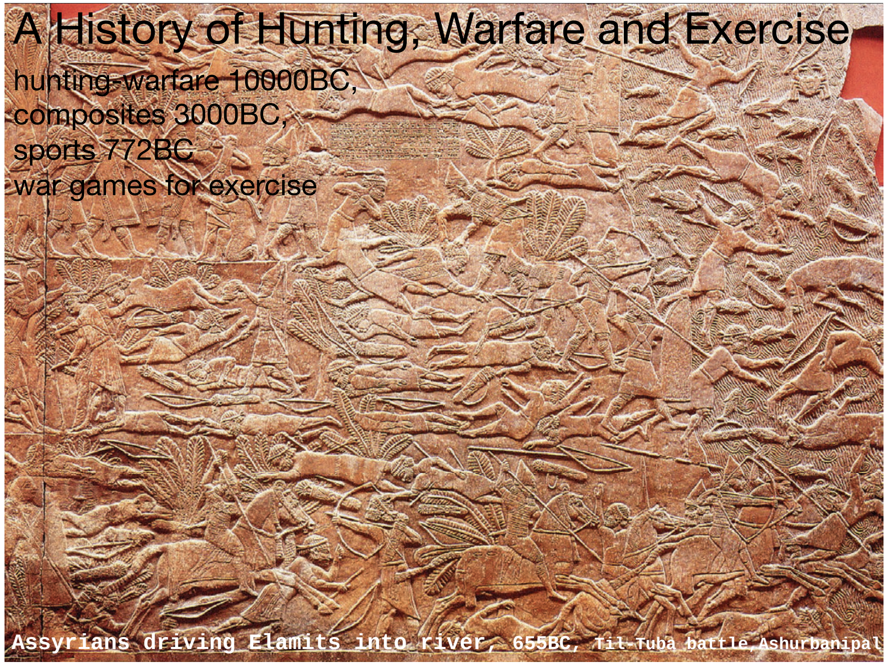
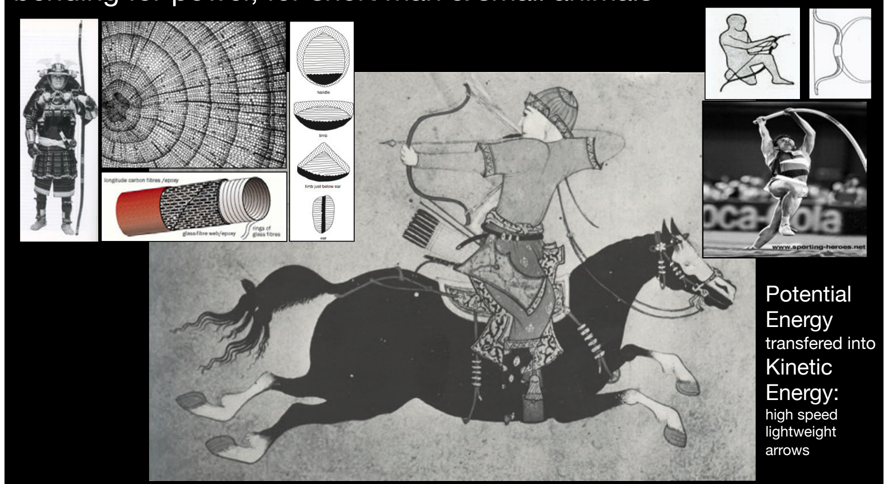




Ancient Lightweight Engineering

bending for power, for short man & small animals

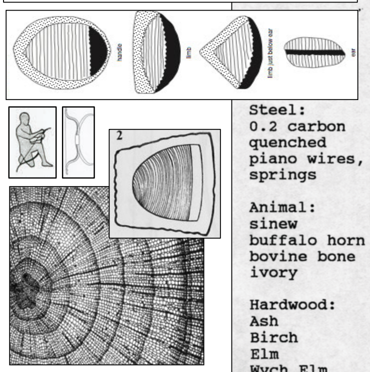


Potential Energy
transfered into
Kinetic Energy:
high speed
lightweight
arrows

**1^{st} laminated composite structures ≈3000BC,
pretensioned, natural polymer composites,
short bow versus long bow, cavalry vs infantry**

Natural Composites

elastic properties compared to steel



nothern hardwoods, sinew and horn a
structural materials for the la
bows and chariots from Mesopotamia

taxus baccata is used for the media

horn, a natural thermoplastic polym
applied in the compression loaded a

sinew, superior in tension, was ap
and bow-reinforcement; more in general it was used as a shrinking (smart) robe to incapsulate and to connect different components.

FROM ABSOLUTE TO SPECIFIC PROPERTIES

	density	Young's Modulus	Yield Stress	Yield Strain	Elastic Energy/ Weight
	kg/m3	N/m2	N/m2	%	J/kg
	(*03)	(*09)	(*06)	-	-
Steel:					
0.2 carbon quenched	7.8	210	773	.2	99
piano wires, springs	7.8	210	3100	.8	1590
Animal:					
sinew	1.3	1.24	103	4.1	1620
buffalo horn	1.3	2.65	-124	-3.2	1530
bovine bone	2.1	22.6	-254	-1.4	846
ivory	1.9	17.5	217	1.2	685
Hardwood:					
Ash	.69	13.4	165	1.	1196
Birch	.65	16.5	137	1.	1050
Elm	.46	7.0	68	1.	740
Wych Elm	.55	10.9	105	1.	950
Oak	.69	13.0	97	1.	703
Softwood:					
Scots Pine	.46	9.9	89	.9	870
Taxus brevifolia	.63	10.0	116	1.3	1100

pretension string, multiply $E_{pot.stored}$

Ultimate Lightness

TEXTILES, FLOPPY, STRESSED AND FROZEN

textile structures in aerospace

George Cayley's paradigm ca.1799

Frozen textile = composite structure
Segregate functions to solve 'design'problems

Classic Greek: soldiers & sportsman

hoplits trained to go on war
ritual sport games to be trained

Fallanx,

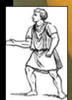
spears and shields in closed ranks

potential energy
low speed
big mass

Greeks: organized games when no war, when war no games (≈772BC)

ADAM'S COSTUME

Clothed and cladded


from floppy wool, silk & cotton
tunica's, shirts & trousers
to smart synthetic cocoons
and armor


Female, Scots, judges, prof's, cardinals & popes dress Greek,
Most men and uniformed professionals dress like Asians

DRESSED TO HORSE

classic sport tunica, trousers, pants

Partians on roadless steps:

provoke, hit & run (partian shot) to anull supplies

Crassus
Napoleon
Hitler

≈ 1000BC Greek horsemen: no pants, saddles and stirrups ≠ Partians

Horsemen, Cavalry, Sportsmen

top horses, a matter of domestication, selection by arching and breeding

≈ 3000BC C&E Asians: inventors of pants, saddles, stirrups, bows & flexible armor: lamela of leather, ceramics or chainmail

Soldiers, Military & Engineers

A Roman Soldier's Load

according to Vegetius

H>1.65 -1.80m, 70kg?:

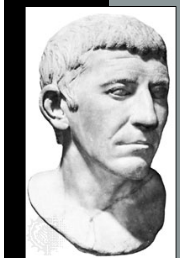
1 day march ≈ 32km
trained to carry ≈ 32kg

16kg cloth, equipment, arms and necessaries

16kg of solid food for < 10-11 days marching

Roman soldiers: engineers and buiders of infra structure & supply chains to go on war/defence

Gnaius Domitius Corbulo > 47 AD praetor creator



NERO'S PROUD (PARTIANS) & VICTIM
66 AD

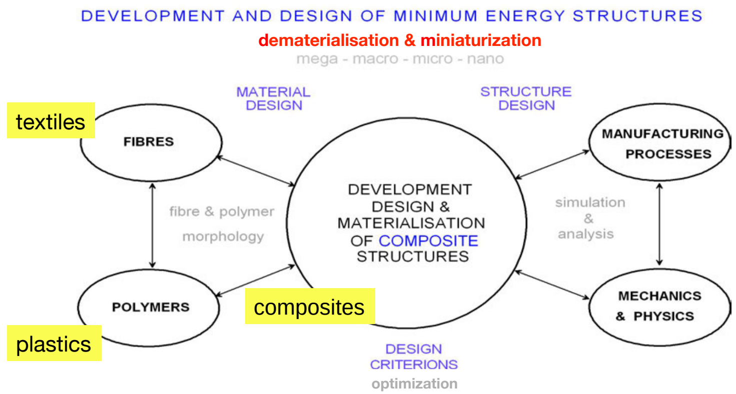
WARRIOR & ENGINEER

➢ 1850 Delft:
civil engineering
i.s.o.
military engineering

Romans: military engineers, infra structures, equipment & cities

DESIGN and PRODUCTION of Composite Structures

Design and Development Strategy



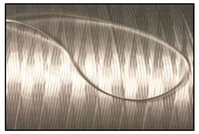
TU Delft

integration vs. segregation
novel fibre-polymer composites
downstream manufacturing

reduction of costs & energy
reduction of emissions & waste
multidisciplinary R&D

Fibre Materials & Structure Efficiency

elastic properties of
natural and synthetic fibres
compared to steel wires



material		density ρ 10^3 kg/m^3	Young's modulus E 10^9 N/m^2	yield stress s 10^6 N/m^2	specific modulus E/ρ 10^6 m^2/s^2	specific strength σ/ρ 10^3 m^2/s^2
steel	piano wire	7.8	210	3100	27	397
natural fibres	jute	1.46	10-25	400-800	12	411
	hemp	1.48	26-30	550-900	19	490
	sisal	1.33	46	700	35	526
synthetic organic fibres	HT-carbon T300	1.76	230	3530	131	2010
	HM-aramide	1.45	133	3500	78	2410
inorganic fibres	E-glass	2.58	73	3450	28	1340

Cytec (Solvay)
Zoltec
Toray
Toho
SGL (BMW)
Hexcel
Mitsubishi
Nippon Graphite

Dupont, Teijin,
DSM, Toyobo

PPG
Owens Corning
St Gobain

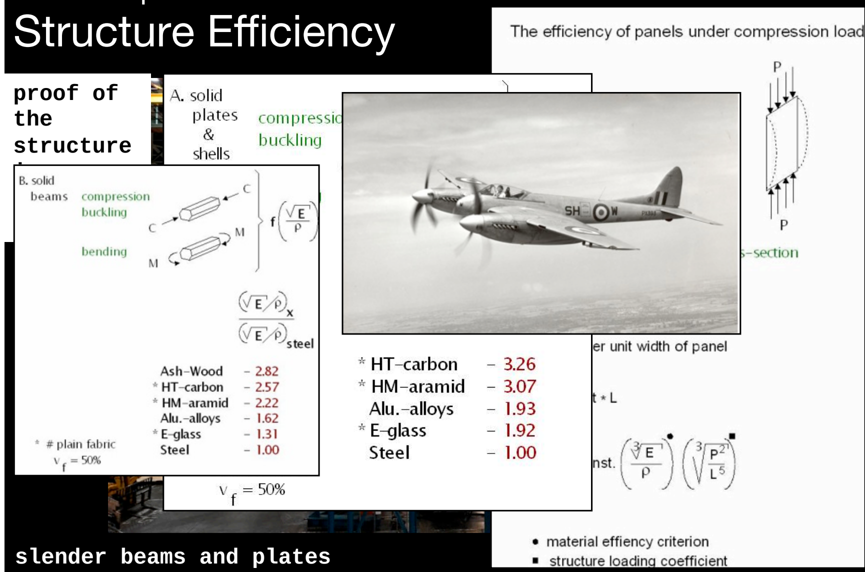
Bekaert

Carbon fibres	*light fast structures*
Glass fibres	*non magnetic structures*
Aramide & UHMW PE fibres	*light armor*
Metal fibres	*conductive structures*

material specific efficiencies determine:

Structure Efficiency

proof of the structure

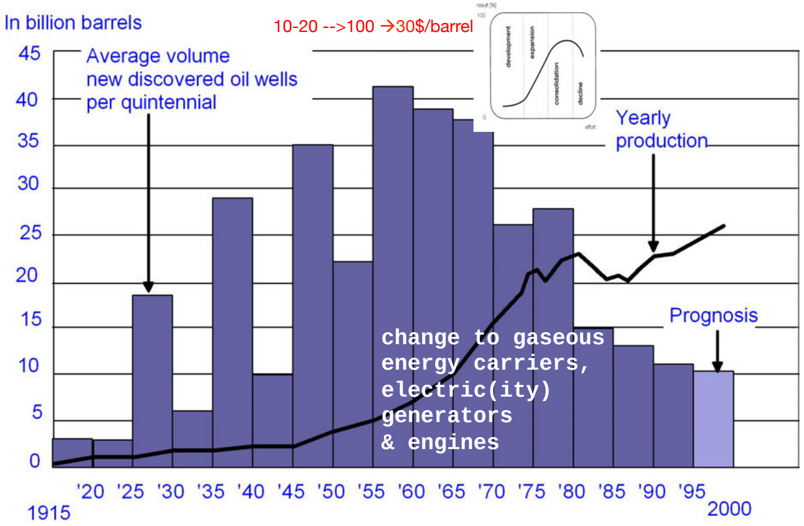


slender beams and plates
dominated by bending
or compression buckling

fast and stealthy Mosquito
pinewood laminate structure

Cheap Materials become Scarce, even dumped

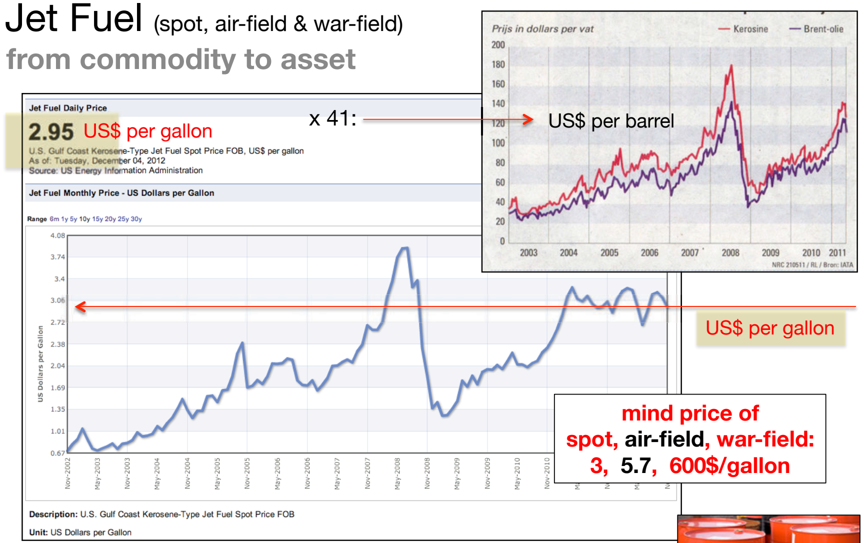
e.g. cheap oil, easy exploitable wells, new circular economies, EC2020



liquid fuel history: 'a one century history of slash and burn'

Jet Fuel (spot, air-field & war-field)

from commodity to asset



1.58$/lt = 5.67$/Usgallon, CHC Den Helder, 2012
average fuel price airfield
1 USgallon = 3.8lt, 41Usgallon = 1USbarrel = 159lt

Canadian Army

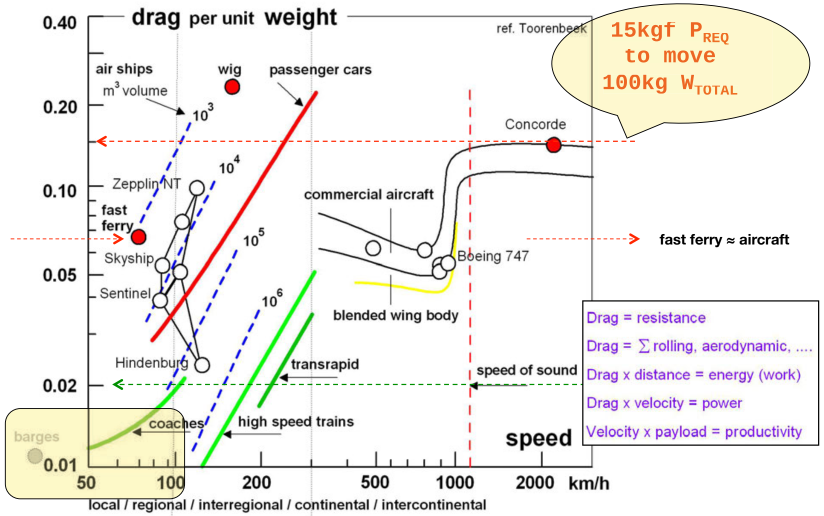
on the road to Kandahar

The US Army directly uses only
~$0.2 billion worth of fuel a year
but pays
~$3.2 billion a year to maintain
20,000 active-duty personnel
and
40,000 reserve personnel
to move that fuel

RMI Rocky Mountain Institute, 2000$

Transport Systems (price of speed, G. Gabrielli – Th. von Kármán, 1950)

force to overcome drag, per unit moving system weight



Transport and velocity domains
Total (system + payload) weight, so reduce system weight, slowdown

Life-time energy savings per 100kg

average values for energy savings by weight reduction

Use phase performance (million km)
0.2
0.2
1.2
3.0
8.0
15
Use phase (years)
20
30
30

Vehicle type	Use phase end energy savings per 100 kg	
Passenger car (Gasoline)	23 GJ (700 litre)	
Passenger car (Diesel)	21 GJ (600 litre)	
Articulated truck	26 GJ (718 litre)	
Subway/ Urban train *	60 GJ (17 MWh)	
Intercity train *	35 GJ (10 MWh)	
High-speed train (ICE)*	44 GJ (12 MWh)	
Vehicle type	**Use phase end energy savings per 100 kg**	
High-speed ferry **	1,400 GJ	42,000lt
Short-distance aircraft **	15,000 GJ	450,000lt
Long-distance aircraft **	20,000 GJ	600,000lt

IFEU 2004, 1GJ is about 30lt kerosine

Aegis Cruisers Hotel Load

e.g. USS Princeton, USS Lake Champlain

The top efficiency quartile of her class burning ~$6 million of oil a year, a third to a half of it to generate electricity
for systems & climate control

CFRP Corvettes
a Δ paradigm ?

RMI Rocky Mountain Institute, 2000

Life time ENERGY SAVINGS High Speed VESSELS

steel

aluminium

GlassFRP
+
added° values
(integrated)

	Steel version	
Total weight	2030t	
Annual energy consumption	2'074'425	
	Aluminium version	Composite version
Total weight	1425t	1439t
Annual energy consumption (GJ)	1'649'760	1'649'760
Relative energy savings	7%	7%
Life-time final energy savings (GJ/100kg)	1404	1437
Life-time primary energy savings (GJ/100kg)	1614	1652
Source: [KTH & ETH 2002] and IFEU assumptions		IFEU 2004

-33%, reduction by weight, in case of CFRP ≈ 60%

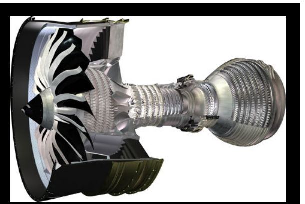
***-7% kerosine**,1650GJ//35MJ/lt* (-14%)

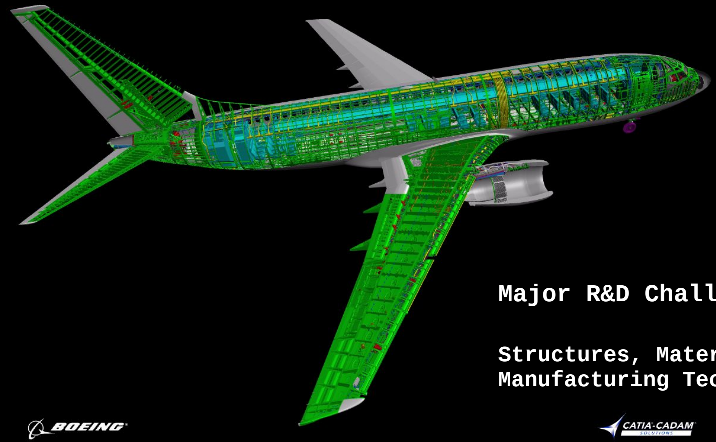
- 47 ton/100kg.lifetime (20yrs) (-95ton/..

Composites benefits: corrosion resistance, thermal & acoustic insolation, mind hotel cost, and free of charge reduced infra-red visibility + stealthy & seamless design possibilities (VABO)

EFFICIENCY improvements

since the 50's,
aerodynamics: L/D ≈ 15%
propulsion: SFC ≈ 40 % (Genx/CSMleap)
structure : 0.50 > OEW/MTOW > 0.60





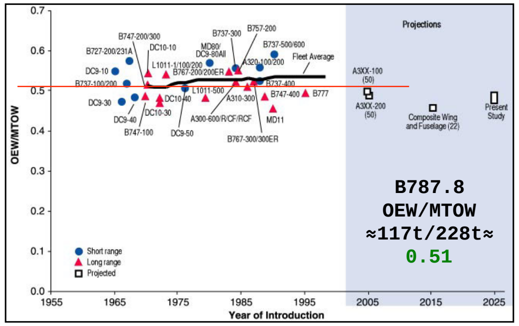
Major R&D Challenges:

Structures, Materials & Manufacturing Techniques

A320/B737 - alikes

structure efficiency
used for aircraft

OEW / MTOW =
42 ton / 74 ton = 0.56



Johnston distribution OEW:

50%: 21ton for systems, crew and power-plant(s)
50%: 21ton for structure in total

- 10.5ton for wing , undercarriage (6%) and movables (6%), (12%=5 ton)
- 10.5ton for fuselage and empennage (13%)
  candidate aluminium structure for change into CFRP
- 16.0ton for wing, fuselage and empennage shell structures (38%)

max weight saving by change is about 25%, equal to 4ton (≈ 10% OEW), for A320/B737 alikes!
(0.51)

Cooled trailer 1995, 3ton weight reduction per trailer!!!!

A320/B737 AIRCRAFT

mass reduction pay off

Energy saving:	667	GJ/year.100kg
Specific energy content:	35	MJ/litre
So fuel saving per year per 100kg:	19000	litre

Sell tickets priced per kilogram not per seat, reduce crew

KLM B787

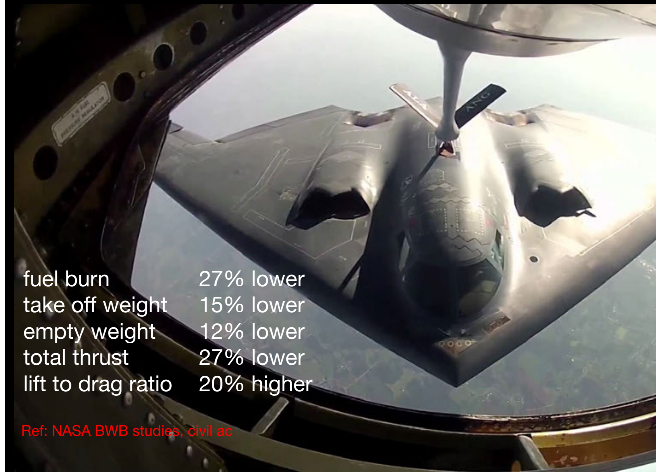
OEW/MTOW = 0.51
increased cabin pressure
increased window area

Allowable design strain 1g fatigue, tension, notched:
AL2024 µstrain <1700, carbon epoxy µstrain <3400

Boeing 787: composites content W_f > 50%, V_f > 70%, 1/R ≈ 2

New Shapes, New Standards

Stealthy B1 Spirit



fuel burn	27% lower
take off weight	15% lower
empty weight	12% lower
total thrust	27% lower
lift to drag ratio	20% higher

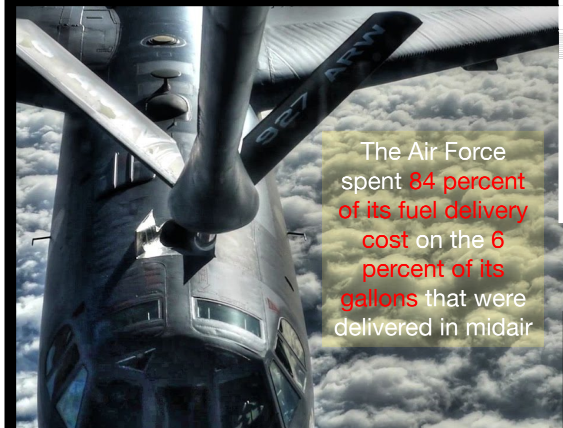
Ref: NASA BWB studies, civil ac

Blend wing & fuselage body,
active i.s.o. Passive stability
Horton Brothers & Jack Northrop in the 1940's

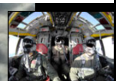
EFFICIENCY improvements

B52H operational since the 50's (non pressurized)

Weight or mass 'fractions'	single aisle %		long range %	
Pay-load		24		18
Fuel		18		37
Systems, crew, etc.	18		12	
Power plant(s)	11	29	10	22
Structure		29		23

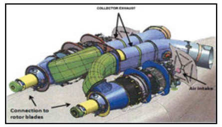


The Air Force spent 84 percent of its fuel delivery cost on the 6 percent of its gallons that were delivered in midair



A refit with today's engines could result in 33% less fuel to fly & 46% increase of range, RMI 2000

AW 136 Weight Saving Benefits, a 'student' guess



CHC, average operations data, Den Helder, 25 heli's
CHC, average fuel price 1.58$/lt *(mind price of spot, air-field, war-field: 3, 5.7, 600$/gallon)*
CHC, average fuel consumption 400lt/hr (460lt/hr USForest)

CHC, 1% TOWeight reduction equals 0.8% Fuel saving

Flight hours	1,200/yr	single heli		
$TOW_{average}$	5,010kg			
$PayLoad_{average}$	1,390kg			
$Fuel\ total_{averafge}$	480,000 lt/yr			
$Fuel\ cost_{average}$	756,000 $/yr			
		Fleet 25 Fuel cost 18,900,000$/yr	1% weight saving (50.1kg)	= 0.8% average fuel saving (lt)
Weight reduction exhaust	60kg pipes stainless steel	-30%=18kg -60%=36kg	-0.36%TOW -0.72%TOW	-0.3%fuel -0.6%fuel
Reductions -30%$W_{exhaust}$	1440lt/yr 2275$/yr	Fleet 25 -36,000 lt/yr -56,880 $/yr	-0.36%TOW	-0.3%fuel
Reductions -60%$W_{exhaust}$	2880lt/yr 4550$/yr	Fleet 25 -72,000lt/yr -113,750$/yr	-0.72%TOW	-0.6%fuel

Januari 2012, ex heat shield reduction & sound reduction benefits

M1 Abram's Hotel Load

Abram's tanks inefficient and mostly idling '68 gas turbine halves their fuel efficiency.



no APU
or Honda
genset

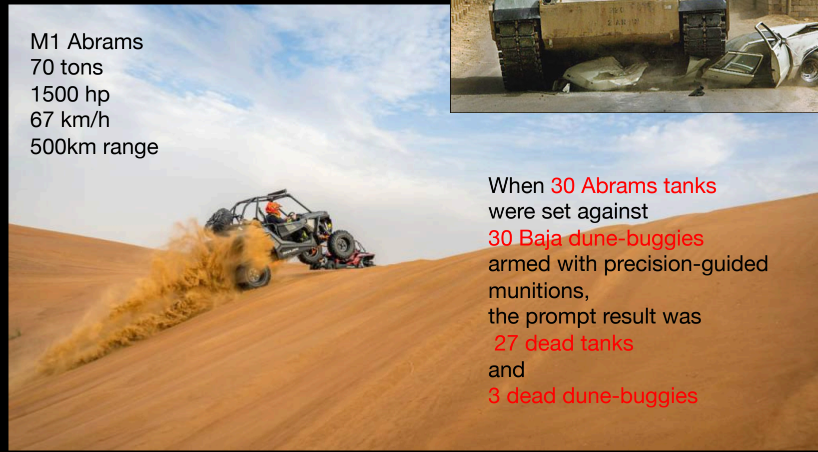
Abrams tanks idle their main engine ~73% of the time, at less than 1% efficiency, to run a small "hotel load"

On the battlefield, rapid fuel delivery can cost $600 a gallon.

This delayed the invasion of Iraq by more than a month to stockpile the extra fuel.


RMI Rocky Mountain Institute, 2000

Heavy Cavalry game against Ultra Lights

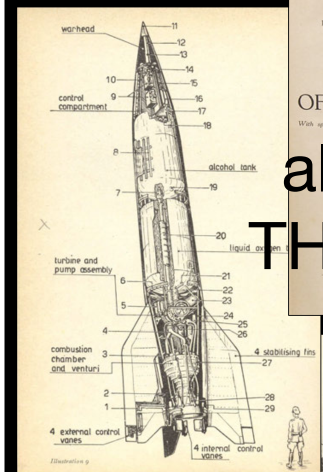



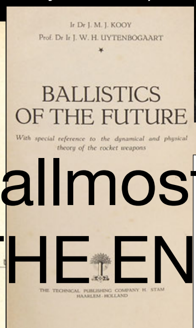
M1 Abrams
70 tons
1500 hp
67 km/h
500km range

When 30 Abrams tanks were set against 30 Baja dune-buggies armed with precision-guided munitions, the prompt result was 27 dead tanks and 3 dead dune-buggies

RMI Rocky Mountain Institute, 2000

Prof. Kooy knowledge development, dissemination (& valorization) at all technical educational levels (LTS, Academy & TH/TU)






allmost THE END

STATE OF THE THIN WALLED SHEET METAL ART TODAY

	empty weight* per unit pay load
SMALL BARGES ≈	0.3
TWINS	1.
BUSES	2.5
CARS***	3. (12) **
CITY TRUCKS	4.
TRAILER INCL TRACTOR	2.
AIRCRAFT SUBSONIC	4.
TRAINS LIGHT RAIL	10
AIRCRAFT SUPERSONIC	12
ORBIT BALLISTIC *	23
ORBIT GLOBAL	66
ORBIT LUNAR	500

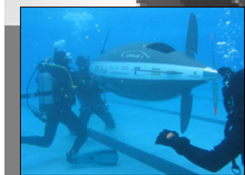
* SYSTEM EMPTY WEIGHT = STRUCTURE + PROPULSION + FUEL
** IN CASE OF ONE OCCUPANT ONLY
*** SUV'S, S-CLASS, almost like ballistic orbit, 8 (25)



Kooy & Uytenbogaart's classic & collector's item

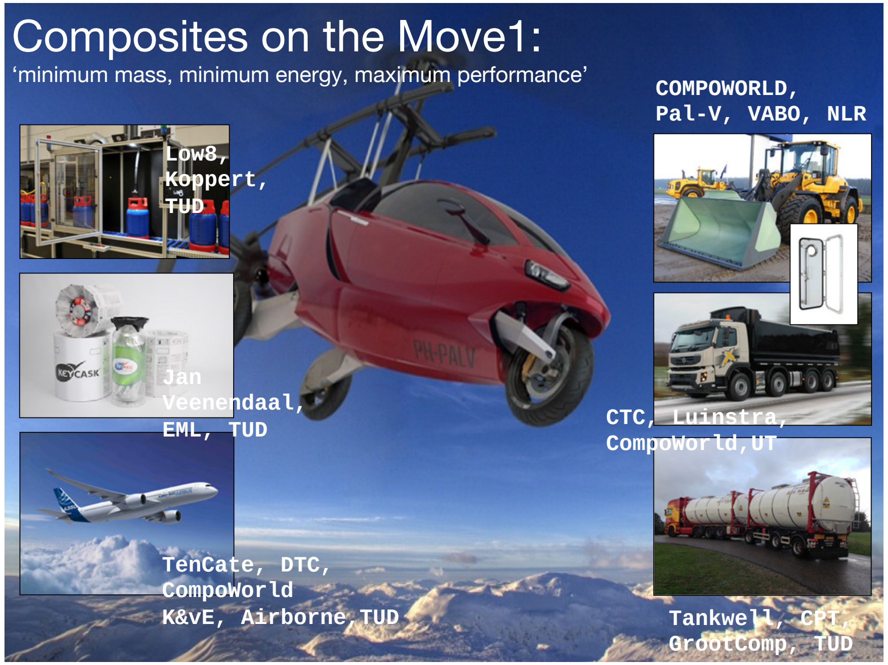
our students, their projects Delft Dream Teams

students are our major and premium resource for innovations

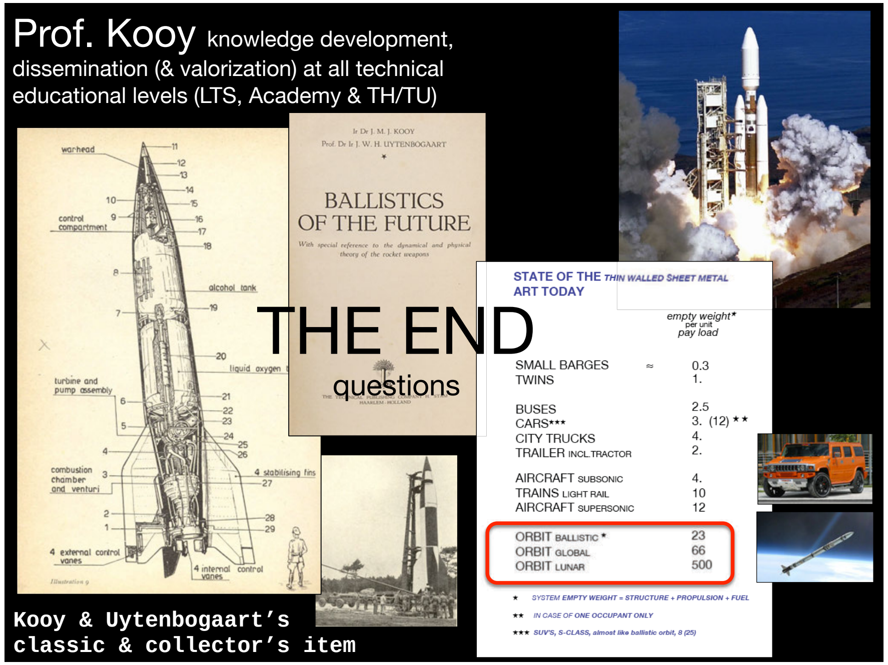



Composite Materials, Structures & Processes
Aerodynamics, Vehicle dynamics, et cetera ....


our students, their project enterprises
Delft Dream Entrepreneurs
New technologies
a challenge
for entrepreneurs
A350-900 AIRBUS
A350
students are our major and
premium
resource for innovations
Taniq
Actiflow
Infinious
ALE
Airborne
K&vE
WMC/CompEx
Bond Laminates
Conform/Hylid
DTC / Mupio
Feltrin Composites
CLC / LS
Euro Enaer (‡)
Senz/Protension
MOCS/CTC
Composite Materials, Structures & Processes
Aerodynamics, Vehicle dynamics, et cetera ....


Composites on the Move1:
'minimum mass, minimum energy, maximum performance'
Low8,
Koppert,
TUD
COMPOWORLD,
Pal-V, VABO, NLR
KEYCASK
Jan
Veenendaal,
EML, TUD
CTC, Luinstra,
CompoWorld, UT
TenCate, DTC,
CompoWorld
K&vE, Airborne, TUD
Tankwell, CPT,
GrootComp, TUD


'TankWell' Composite Containers - CPT - NH
STAINLESS STEEL
replaced
by E-GLASS FRP:
-40% empty weight
reduction
per road transport
>3000kg
more payload
HOYER
• Vessel capacity (31000lt)
• tare weight/pay load
up to 36ton
• Temperature controlled
• max pressure 4 bar
Inter-modal transport containers:
road transport limits capacity, grossweight <44, <40 & <32ton


Prof. Kooy knowledge development,
dissemination (& valorization) at all technical
educational levels (LTS, Academy & TH/TU)
warhead
control compartment
alcohol tank
liquid oxygen
turbine and pump assembly
combustion chamber and venturi
4 stabilising fins
4 external control vanes
4 internal control vanes
Ir Dr J. M. J. KOOY
Prof. Dr Ir J. W. H. UYTENBOGAART
BALLISTICS
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