The Volterra- Environmentally Friendly VTOL Concept Design

VOLTERRA

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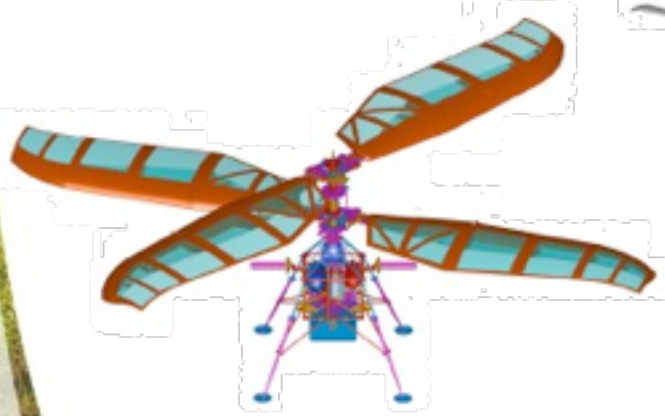
American Helicopter Society Student Design Competition

- Annual partnership with industry designed to simulate the helicopter design process: Request for Proposal
- Graduate/Undergraduate categories
- UMD graduate students take 4 months to write the 120 page proposal
- The University of Maryland has done extremely well in this competition for more than a decade with nine 1st and two 2nd place finishes in the last 11 competitions
- Judging focus is on Innovation, System Performance and System Value



AHS/Eurocopter 2008 RFP Overview

Advanced VTOL Concept – Minimizing Energy Consumption

- Short range (345 mi), medium speed (140 mph)
- 1 + 4 (or 500 kg payload)
- Multi-role military, para-military and civilian capability
- Excellent safety and reliability
- Congested area transport operations
- Operational Capability in 2020
- "SMART-COPTER" must be environmentally friendly:
  - Minimize life cycle energy consumption
  - Minimize pollution (emissions, noise, disposal, etc)
  - MUST BE "GREEN"

RFP Background – EU's Clean Sky

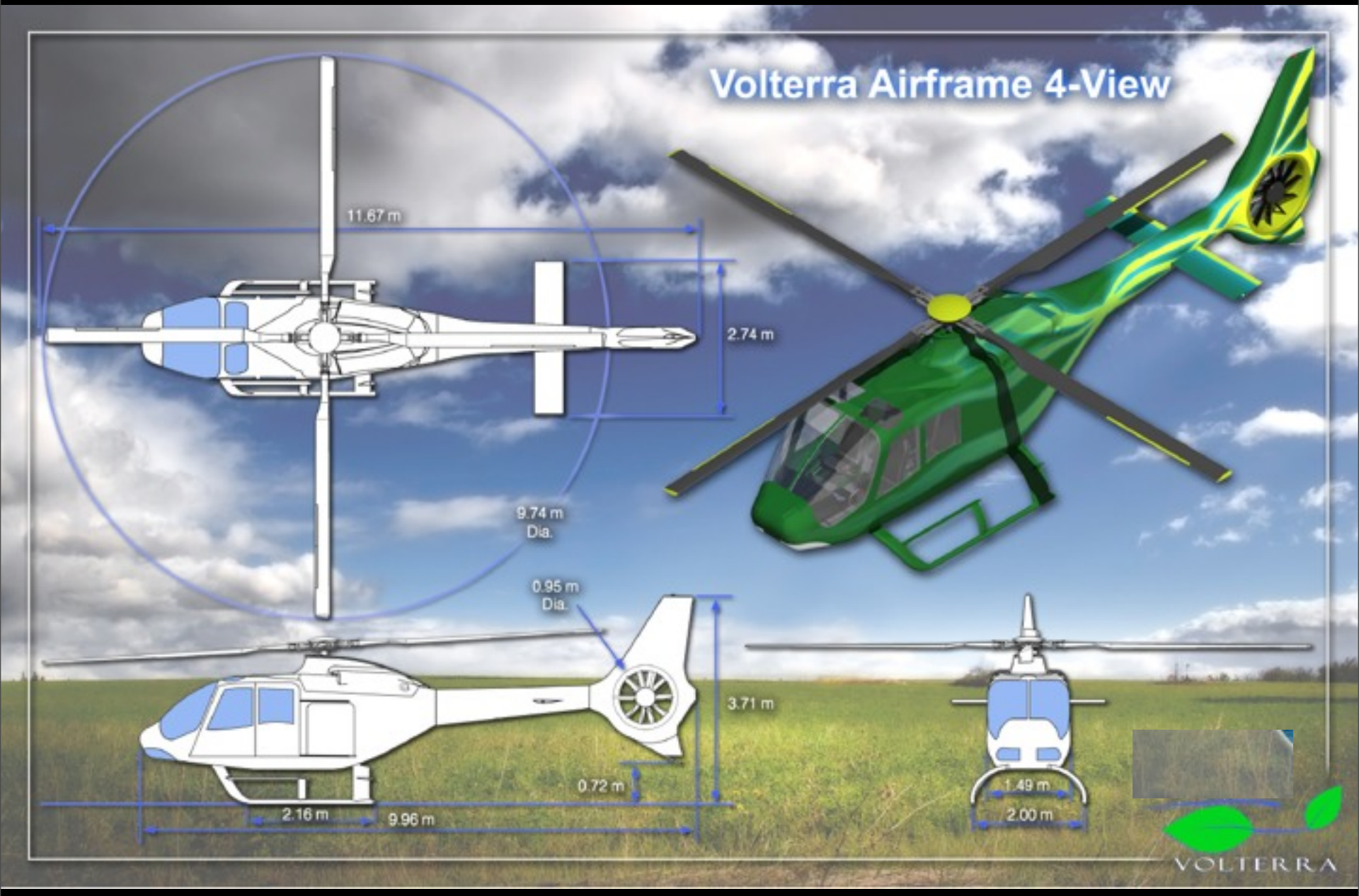
- 2000 – European Research Commissioner Philippe Busquin endorses the idea that current evolutions in technology will not be sufficient to overcome fundamental challenges to progress
- 2001 – Busquin's "Group of Personalities" publishes the report European Aeronautics – A Vision for 2020
- 2001 – The Advisory Council for Aeronautics Research in Europe (ACARE) is founded
- 2002 – SRA 1 (Strategic Research Agenda) is released, detailing research challenges through 2020, broad proposed solution technologies, and a program framework
- 2004 – SRA 2 is released, focusing on air transportation management but also reports:
  - SRA 1 objectives are "not achievable without important breakthroughs both in technology and concepts of operation"
  - No single nation could afford to pursue and develop the required technologies

RFP Background – EU's Clean Sky

- 2006 – Inception of U.S. Commercial Aviation Alternative Fuels Initiative (CAAFI):
  - 5-15 year fuel goals (oil shale, bio diesel, ethanol blends, hydrogen fuel cells for APU)
  - Hydrogen turbines not proposed until after 2021
- 2007 – U.S. Continuous Low Emissions, Energy and Noise (CLEEN) initiative proposed (funded as of 2008)
- 2007 – Atlantic Interoperability Initiative to Reduce Emissions (AIRE) formed as a partnership between European Union and the U.S.
- 2008 – European Clean Sky program officially begins. AgustaWestland hosts kickoff meeting for Green Rotorcraft ITD which focuses on (only a 7 year timeframe!):
  - Innovative rotor blades
  - Engine installation for noise reduction
  - Lower airframe drag
  - Diesel technology
  - Reduced fuel consumption
  - Replacement of hydraulic actuators with electrical systems

Clean Sky Program Defined Challenges

1. Quality and Affordability
2. The Environment (2020 timeframe)
   - Reduce fuel consumption and CO_2 emissions by 50%
   - Reduce perceived external noise by 50%
   - Reduce NO_x by 80%
   - demonstrate sensitivity to society's needs. Become "stewards of the environment"
   - Make "substantial" progress in reducing the environmental impact over the vehicle's life cycle
3. Safety
4. Air Transport System Efficiency
5. Security


Volterra Airframe 4-View
11.67 m
2.74 m
9.74 m
Dia.
0.95 m
Dia.
3.71 m
0.72 m
2.16 m
9.96 m
1.49 m
2.00 m
VOLTERRA

Volterra Performance Summary

	Volterra	EC-120B	Bell 206B3
Standard Accommodation	1 + 4	2 + 3	1 + 4
Design Gross Weight	1750 kg (3858 lb)	1715 kg (3780 lb)	1451 kg (3198 lb)
Useful load	500 kg (1102 lb)	404 kg (891 lb)	393 kg (866 lb)
Fuel Capacity	150 kg (43.5 gal)	321 kg (107 gal)	281 kg (91 gal)
Speed for best range	198 km/hr (107 knots)	204 km/hr (110 knots)	213 km/hr (115 knots)
Speed for best endurance	124 km/hr (67 knots)	120 km/hr (65 knots)	96 km/hr (52 knots)
Fast cruise speed	222 km/hr (120 knots)	222 km/hr (120 knots)	223 km/hr (121 knots)
HOGE Ceiling (ISA+20 deg C)	2238 m (7343 ft)	518 m (1700 ft)	914 m (2998 ft)
Maximum range	708 km (382 n.m.)	710 km (383 n.m.)	693 km (374 n.m.)
Maximum endurance	3 hr 34 min	4 hr 19 min	4 hr 30 min
Specific fuel consumption (SFC)	0.206 kg/kw-hr	0.26 kg/kw-hr	0.33 kg/kw-hr
Acquisition price	$0.9 million	$1.45 million	$1.3 million
Direct operating costs (DOC)	$ 104 / FH	$ 231 / FH	$ 235 / FH

Enabling Components and Technologies

- Materials Selection
  - Production and Manufacturing
  - Service life
  - Recycling, reusing and end-of-life concerns
- Main Rotor
- Avionics
- Powerplant
- Acoustic Emissions Reduction

Service Life

- **30% reduction in SFC** leads to dramatic reductions in CO_2, NOX, unburned hydrocarbons, and fuel costs
- Lean burning, turbocharged, low-maintenance OPOC engine results in further **reductions in NOX emissions** and **low maintenance cost**
- Aeroacoustic rotor design, low tip speed, flight path management system and active noise reduction flaps result in a **10dB reduction in perceived noise** compared to similar helicopters
- Unevenly spaced Fenestron blades and careful duct design drastically reduce overhead annoyance level
- **Multi-fuel capable system** (diesel, gasoline, biofuel, JP8, natural gas, hydrogen)
- **All-Electric Helicopter** (No Environmentally Hazardous Hydraulic Fluids)
- Biologically Inspired, **Low Drag** Fuselage Design

Materials Production and Manufacturing

- 65% Thermoplastic composite structure
- 40x **Less energy** is consumed in the manufacture of PEEK based components
- 28% Lightweight aluminum structure
- Minimal use of Titanium due to high CO_2 emissions during production
- Increased use of structural welding for minimization of fastener use

End-of-Life Recyclability

- PEEK composite components can be remolded or **recycled** by being chopped into short fiber components, extending the service life of the material
- **Environmentally friendly** bio-polymer seat cushions (soy based)
- Hexavalent-Chromium-Free paints and electronics
- Heavy use of compatible aluminum alloys for **easy recyclability**
- High energy density batteries to minimize the mass of hazardous chemicals onboard
- Minimal use of fasteners make disassembly of the Volterra **less energy intensive**

The Era of Green

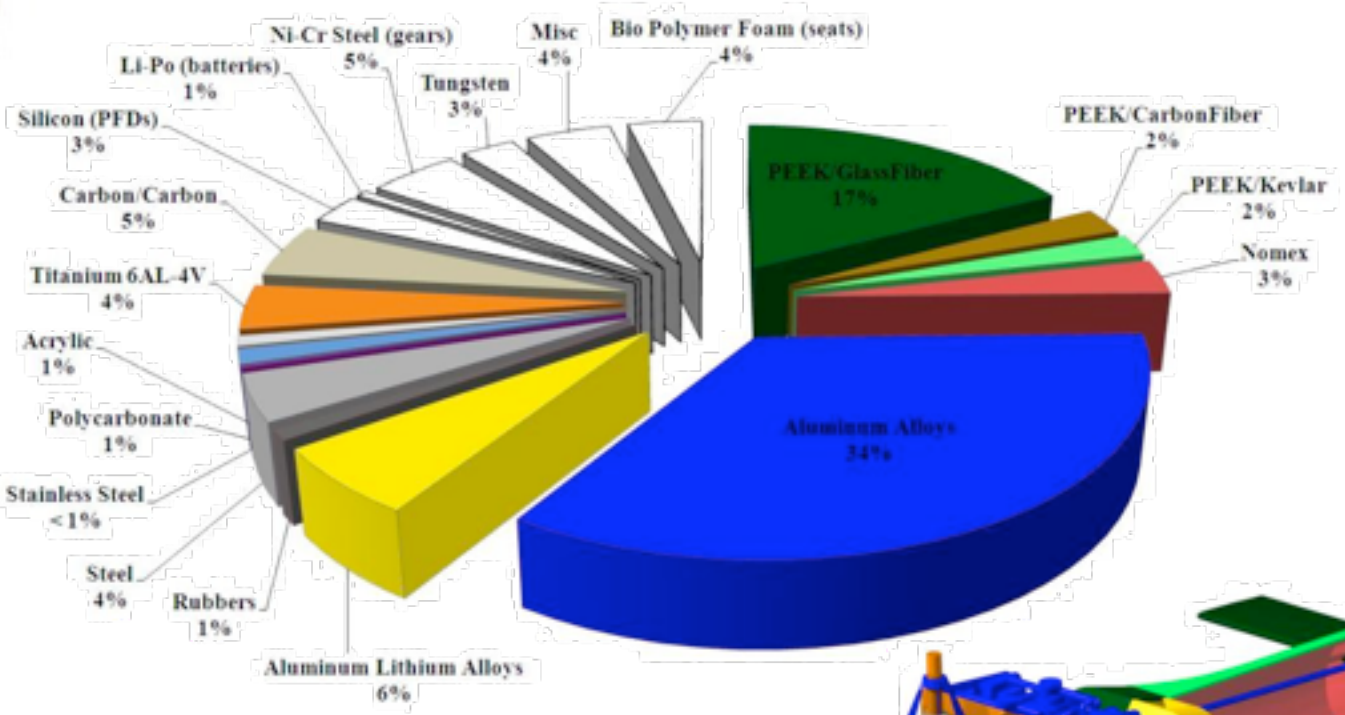
Foldout 7

VOLTERRA

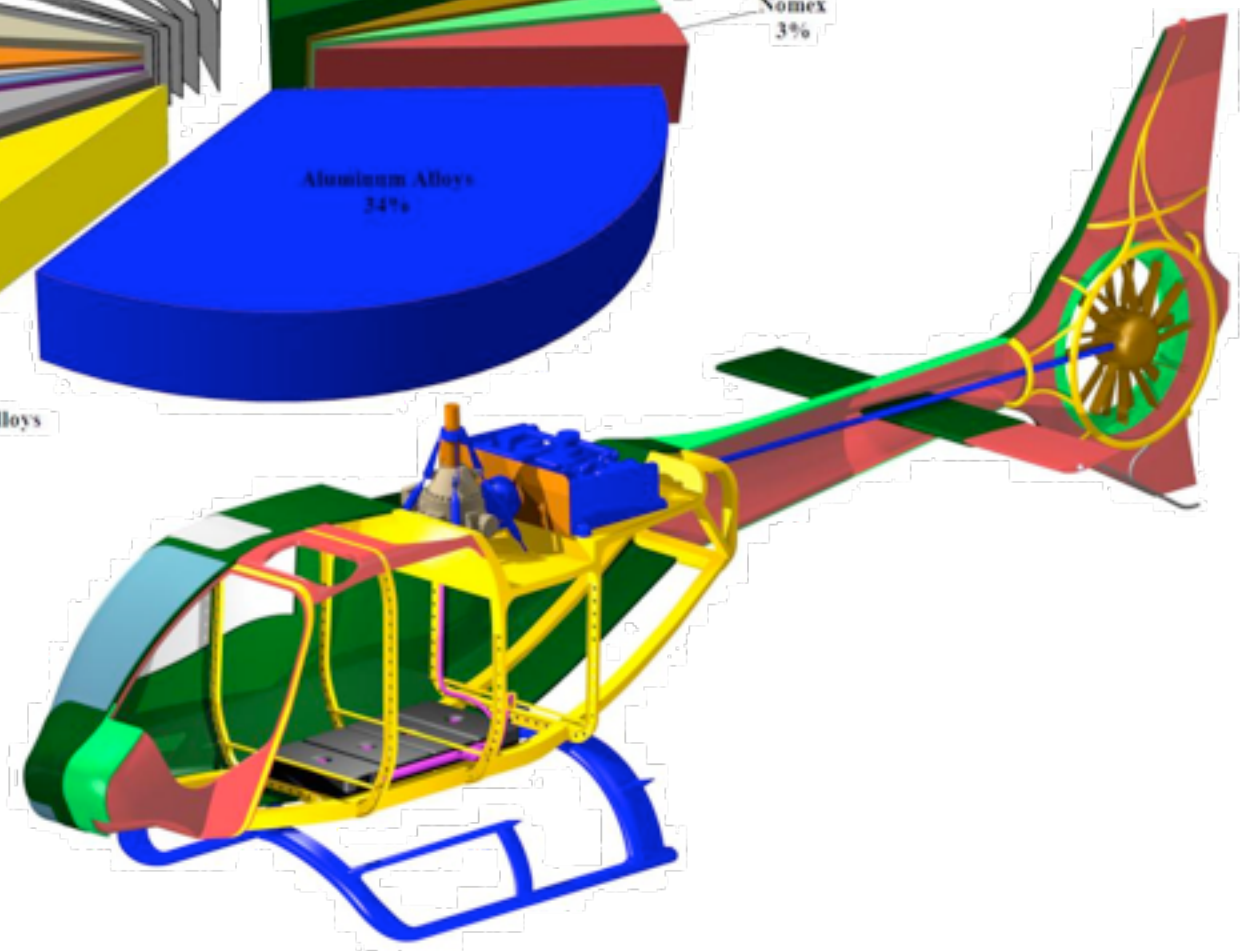
Raw Material Energy Costs

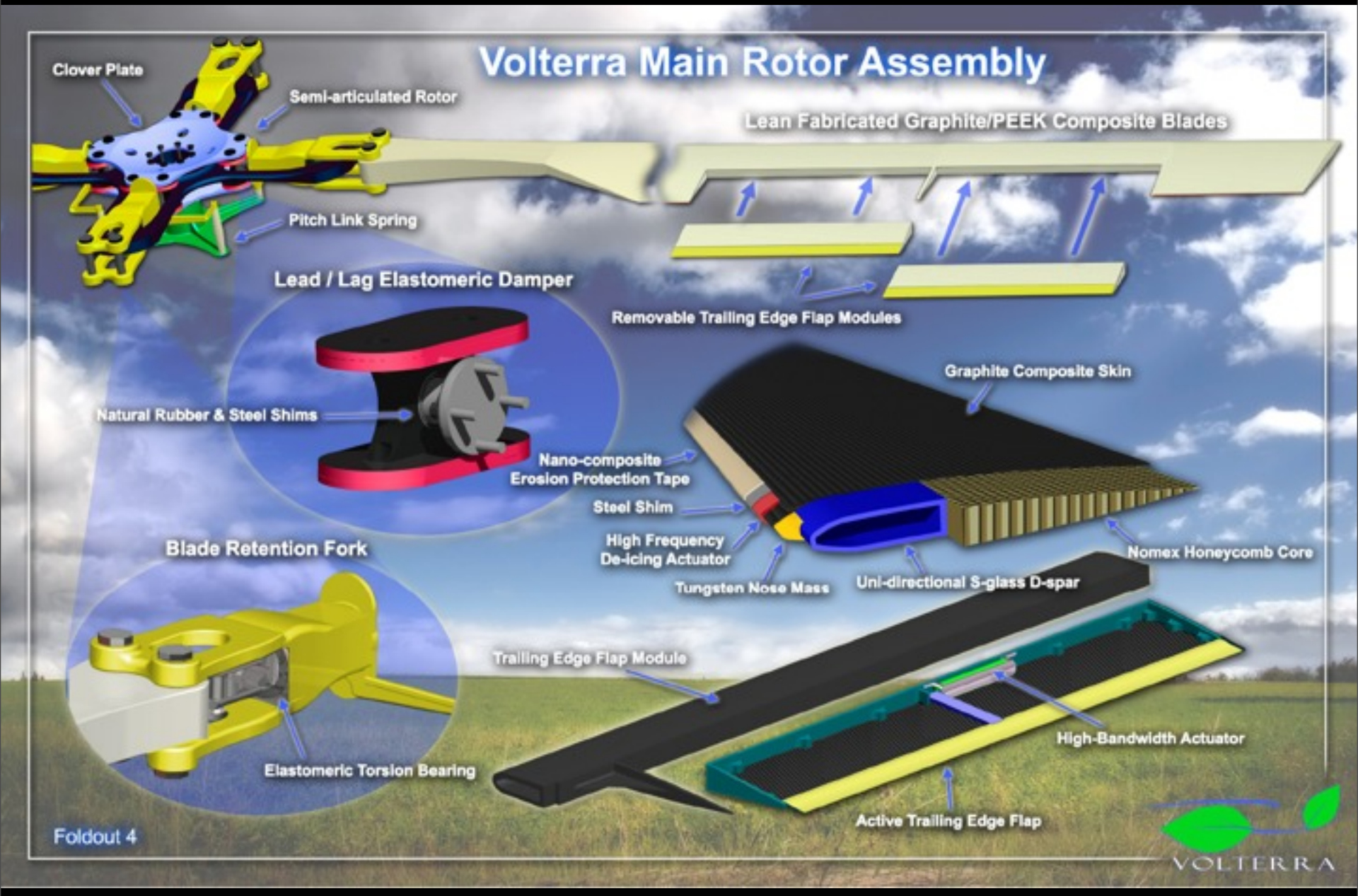
Material	Typical Helictoper Uses	Production Energy	
		Energy (MJ/kg)	CO_2 Burden (kg/kg)
Titanium 6AL-4V	Engine, main rotor shaft	885	41.7
PEEK/Kevlar	Tail boom, fan duct	623	35.7
PEEK/CarbonFiber	Main/Tail rotor skin	509	33.7
PEEK/GlassFiber	Main rotor, empennage	330	20.7
Tungsten	Main rotor tip-weights	313	19.7
Aluminum Alloys	Engine, skids, hub	190	12
Ni-Cr Steel	Transmission	130	8
Polycarbonate (PC)	Front windshield	110	4
Nomex (nylon)	Main rotor, stabilizers	105	4
Epoxy	Paints	90	3.2
Lithium/Polymer	Batteries	68	--
Stainless Steel	Fuel lines	65	5.4
Copper	Wiring, slip-ring	63	4
Silicon	Avionics, wiring	56.9	3.2
Natural Rubber	Hub bearings, fuel tanks	40	-0.5
Steel	Engine pistons, empennage	25	2
Iron	Electric motors	16.4	1

Materials Breakdown for the Volterra



Percentages by weight




Volterra Main Rotor Assembly
Clover Plate
Semi-articulated Rotor
Lean Fabricated Graphite/PEEK Composite Blades
Pitch Link Spring
Lead / Lag Elastomeric Damper
Removable Trailing Edge Flap Modules
Graphite Composite Skin
Natural Rubber & Steel Shims
Nano-composite
Erosion Protection Tape
Steel Shim
High Frequency
De-icing Actuator
Tungsten Nose Mass
Uni-directional S-glass D-spar
Nomex Honeycomb Core
Blade Retention Fork
Trailing Edge Flap Module
High-Bandwidth Actuator
Elastomeric Torsion Bearing
Active Trailing Edge Flap
Foldout 4
VOLTERRA

Pilot View
Barometric Pressure Altitude Encoder
Collision Avoidance Weather System
VHF/VOR/DME
Engine Controls/HUMS
Gyro/Horizon/Attitude
Circuit Breakers
De-Ice/Anti-Ice/Pitot Heat
Planning Configuration
Google Earth 3D Terrain Interface
Communications configuration
Backlit Aluminum Keyboard
Cupholders
Fire Extinguisher
Lighting/Cabin Temp
Cockpit Layout
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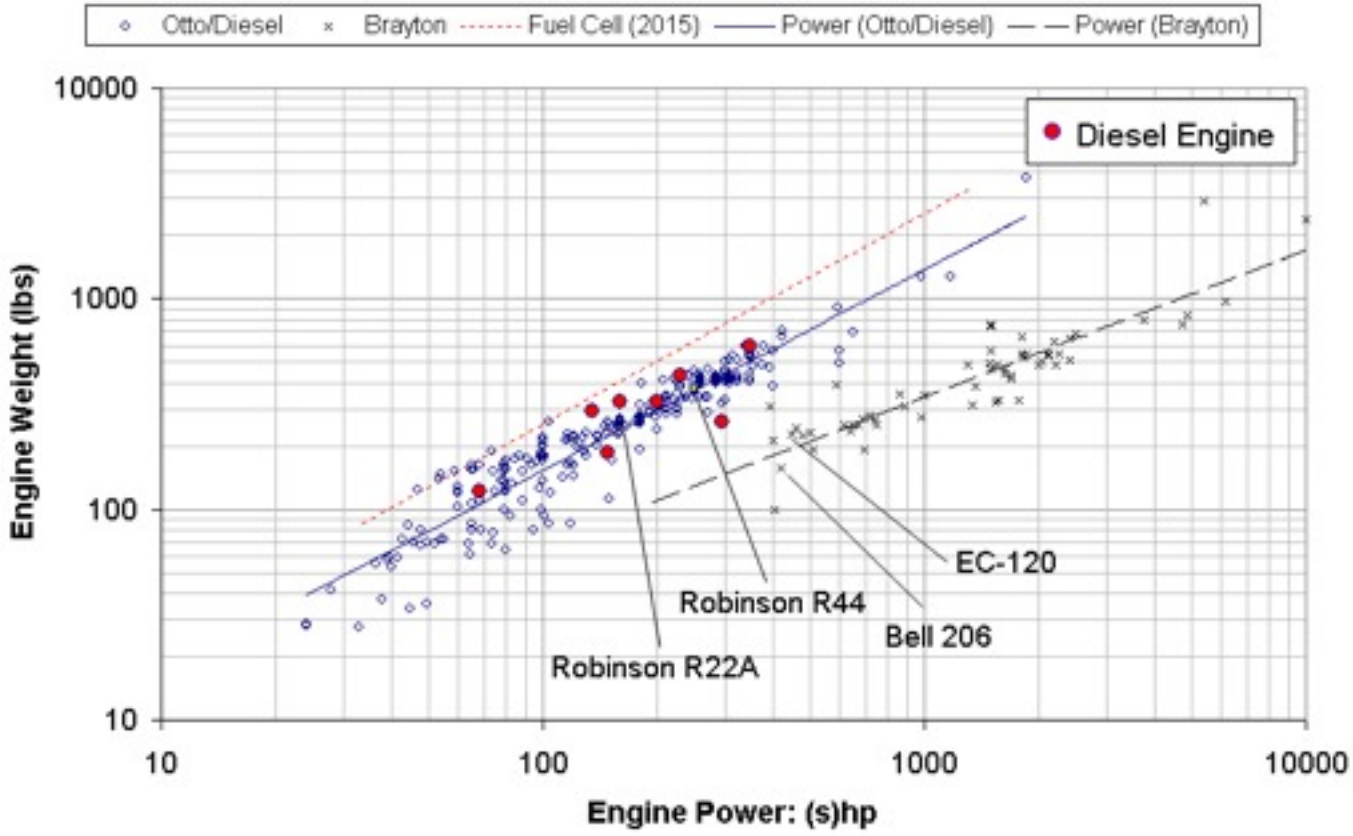
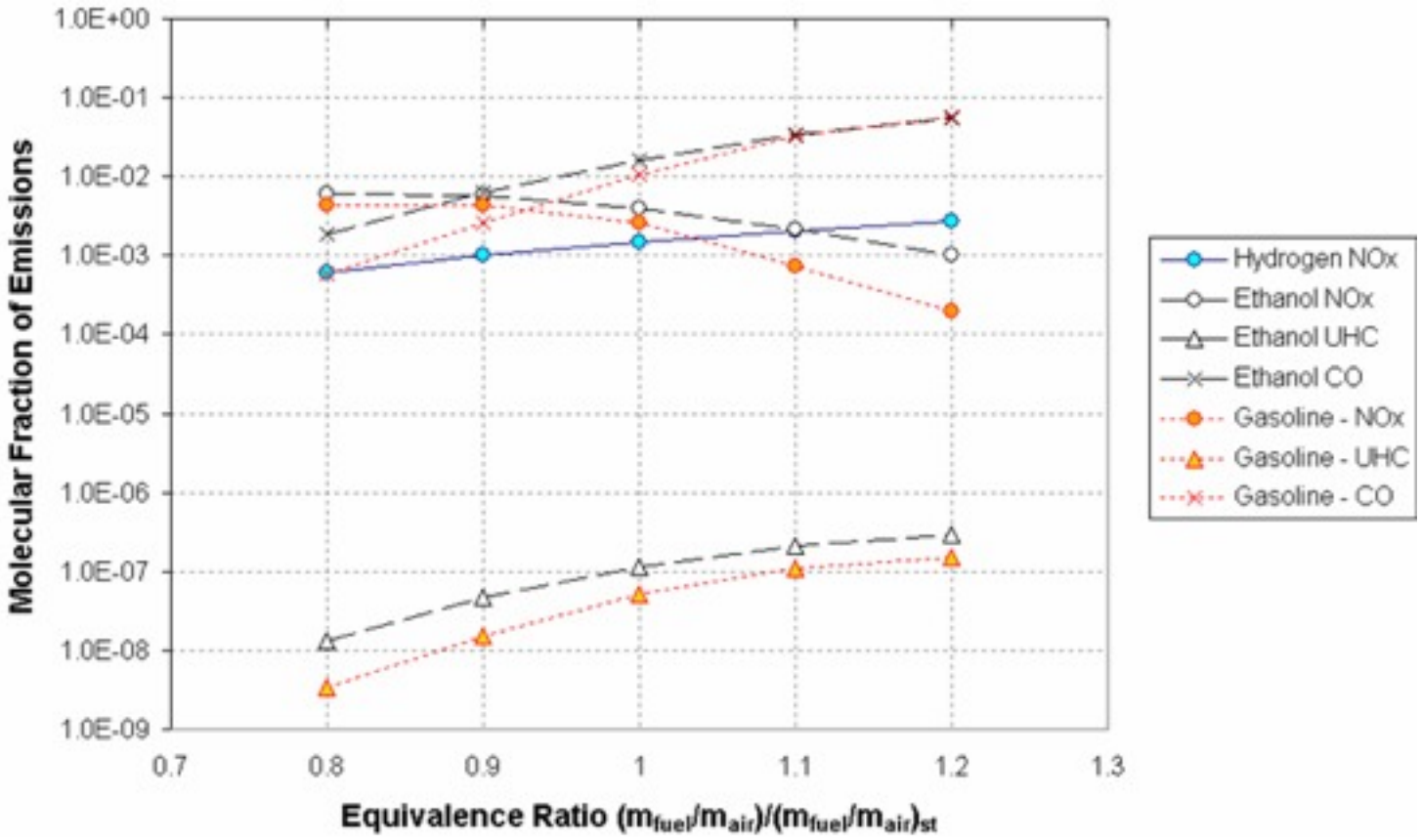
Powerplant - Piston vs. Turbine



- Brayton cycle turbines generally offer higher power-to-weight ratios than Otto/Diesel piston engines
- Piston engine types are typically cheaper
- Crossover in dominant engine type near 400 shp

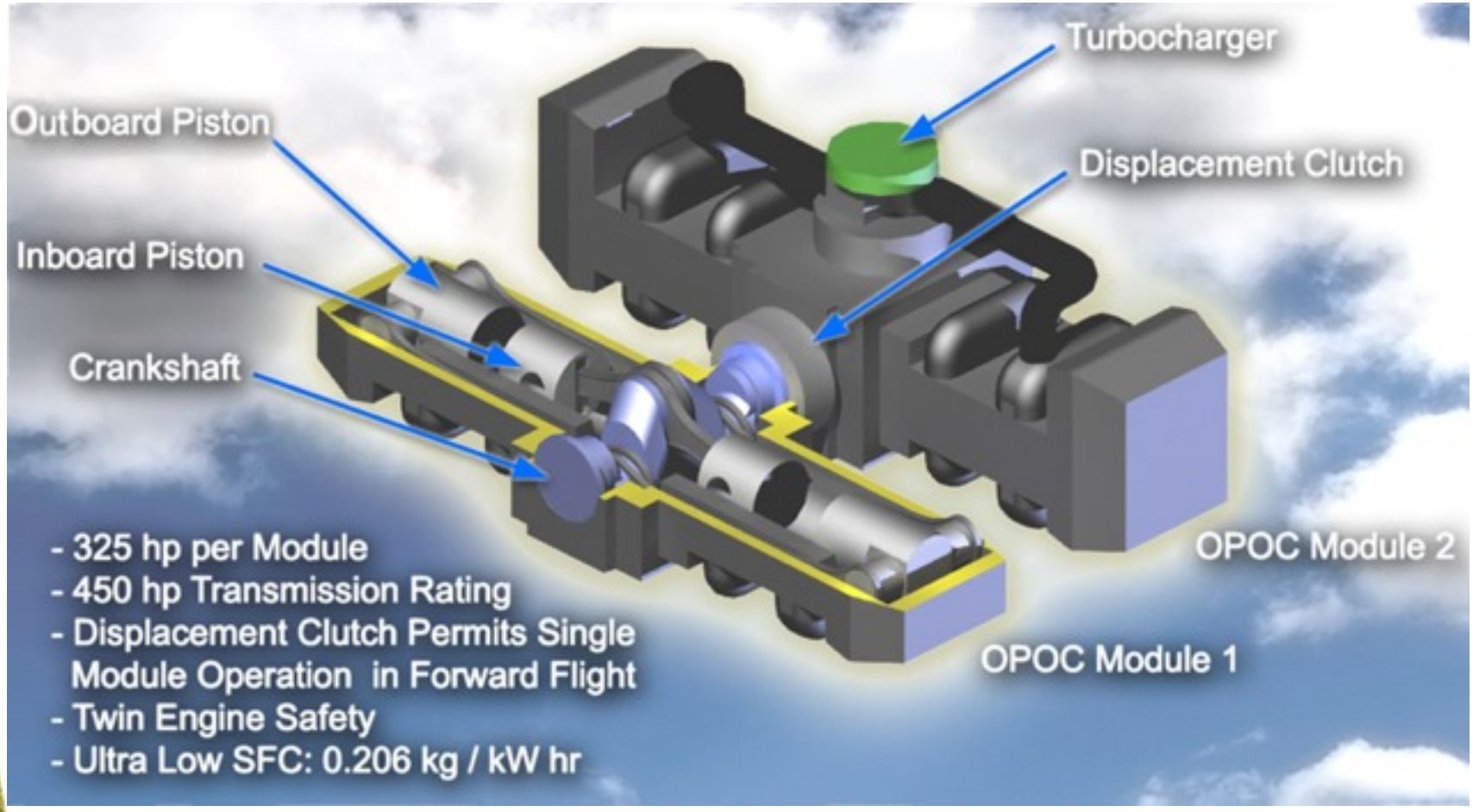
Powerplant - Fuel Selection



- Emissions are calculated by an in-house developed chemical equilibrium solver
- Ethanol emissions are actually worse than carbon based fuels!
- Bottom line: There is no clear alternative fuel from an emissions standpoint

Powerplant - OPOC Engine

Opposed-Piston/Opposed-Cylinder

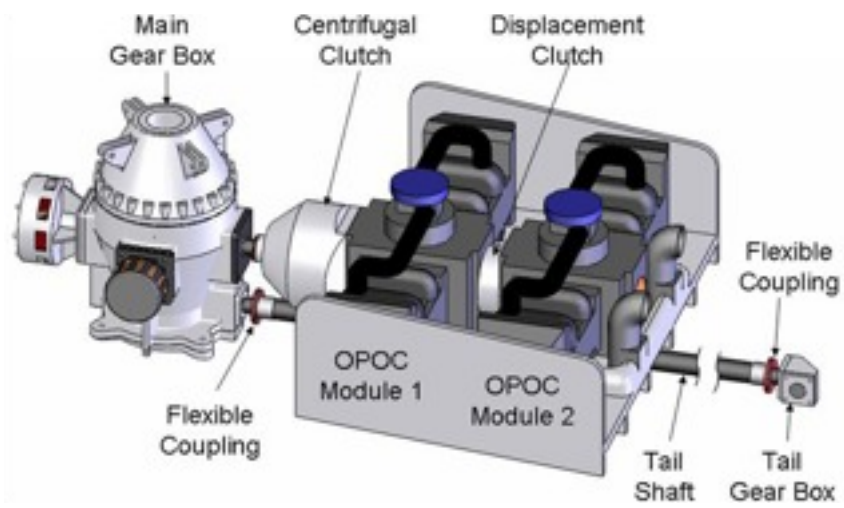


Powerplant - OPOC Engine

Engine	Type	Specific Power (kW/kg)	SFC (lb/hp-hr)	SFC (kg/kW-hr)
Teledyne Brown Engine	Piston	1.2	0.550	0.335
Rolls-Royce 250-C30P	Turbine	2.5	0.592	0.36
Turbomeca TM-333	Turbine	2.8	0.513	0.312
OPOC Engine	Piston	1.96	0.339	0.206

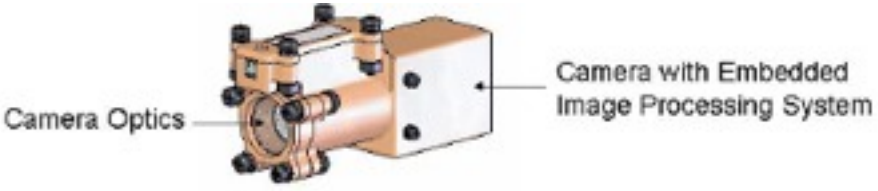
In summary the OPOC is:

- Cost effective
- Highly efficient
- Cleaner burning
- Multi-module versatile
- Multi-fuel versatile

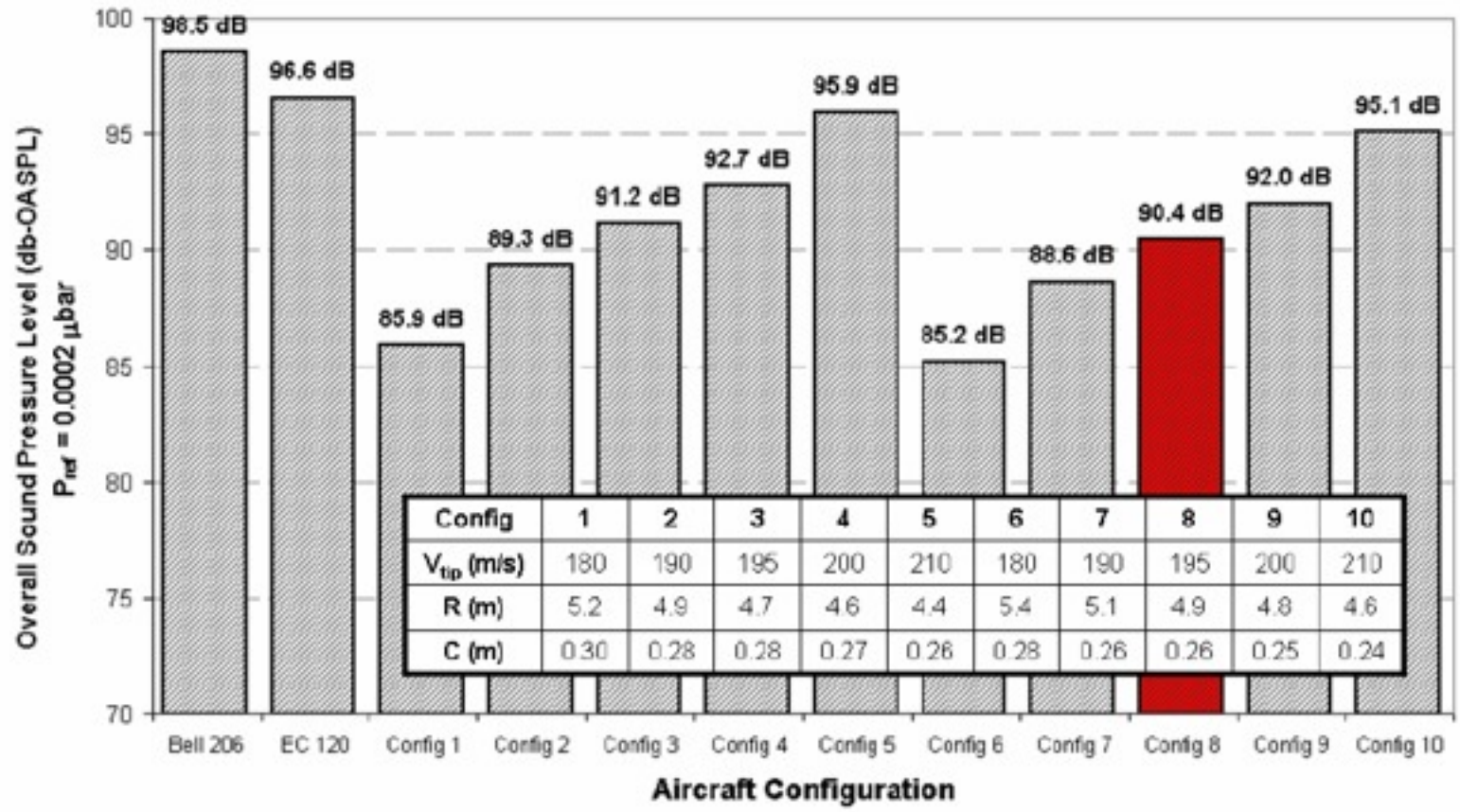


Acoustic Emission Reductions

- Main-rotor tip speed, diameter, chord and aspect ratio are optimized as practical for low noise production
- Fan-in-fin incorporates unevenly spaced rotors to spread noise over frequency spectrum
- Active noise reduction using trailing-edge flaps
  - Reduces low frequency in-plane noise
  - Essential for reducing detectiblity
- Flight path management with integrated tip-path plane tracking system
  - Provides visual cues to pilots that indicate the potential for high noise production
  - Reduced blade vortex interaction (BVI)



Acoustic Emissions



Config	1	2	3	4	5	6	7	8	9	10
V_{tip} (m/s)	180	190	195	200	210	180	190	195	200	210
R (m)	5.2	4.9	4.7	4.6	4.4	5.4	5.1	4.9	4.8	4.6
C (m)	0.30	0.28	0.28	0.27	0.26	0.28	0.26	0.26	0.25	0.24

- Solutions of the Ffwocs-William-Hawking equation at a given observer distance
- The Volterra's main rotor configuration yields a 6db reduction in SPL over the EC-120

Design Methodology Summary

- Ground-up helicopter design methodology leads to better understanding of environmental issues at the design phases which can most significantly impact the final life-cycle energy costs
- Multiple smaller scale design improvements spread across the entire life cycle lead to large system improvements in a short timeframe – not a necessarily single big innovation

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Life Cycle Environmental Impact

- 30% reduction in Specific Fuel Consumption significantly reduces
  - unburned hydrocarbons
  - NO_x, SO_x, CO_2 and other greenhouse gases
  - carcinogens
- Extensive use of thermoplastic composites
  - Reduced manufacturing energy
  - Improved recyclability and reusability
- "All-electric" helicopter design eliminates environmentally unfriendly hydraulic fluids
- Reduced recycling cost based on careful material and assembly technique choice
- Furnishings and accessories use eco-friendly materials where possible:
  - Bio-foam polymer seat cushions
  - Paints and electronics are free of hexavalent chromium

Standard
EMS
Police / Border Enforcement
VOLTERRA
Mission Profiles
VIP / Corporate
Coast Guard Rescue
Surveillance UAV
VOLTERRA

Welcome to the Era of Green

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