EWADE 2011

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Regional turboprop conversion for AEW&C purposes supposing auxiliary engine installation. Technical and economical analysis

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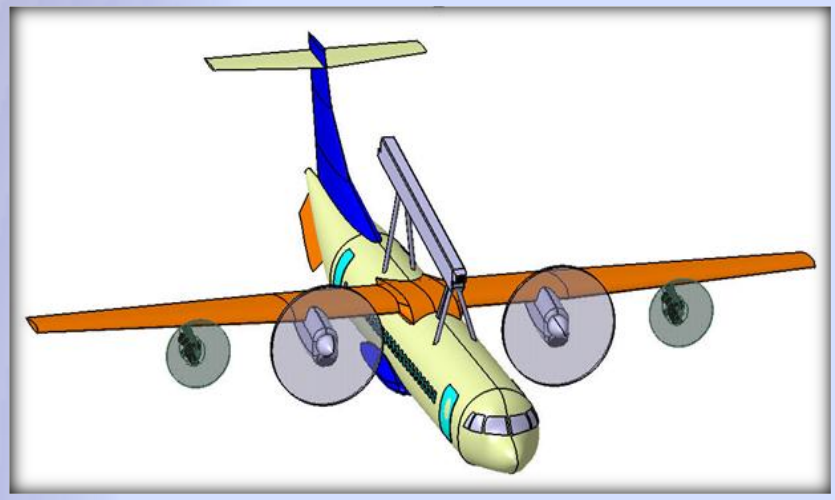
Project scopes

- To Investigate the impact of the conversion of a regional turboprop platform to AEW&C asset

- To technically analyze the hypothesis of realization of a AEW&C asset whose performances are comparable with jet engine aircraft but with fuel consumption advantages of a turboprop engine aircraft

- To perform a effectiveness-cost assessment to demonstrate the validity of the solution in an economical perspective

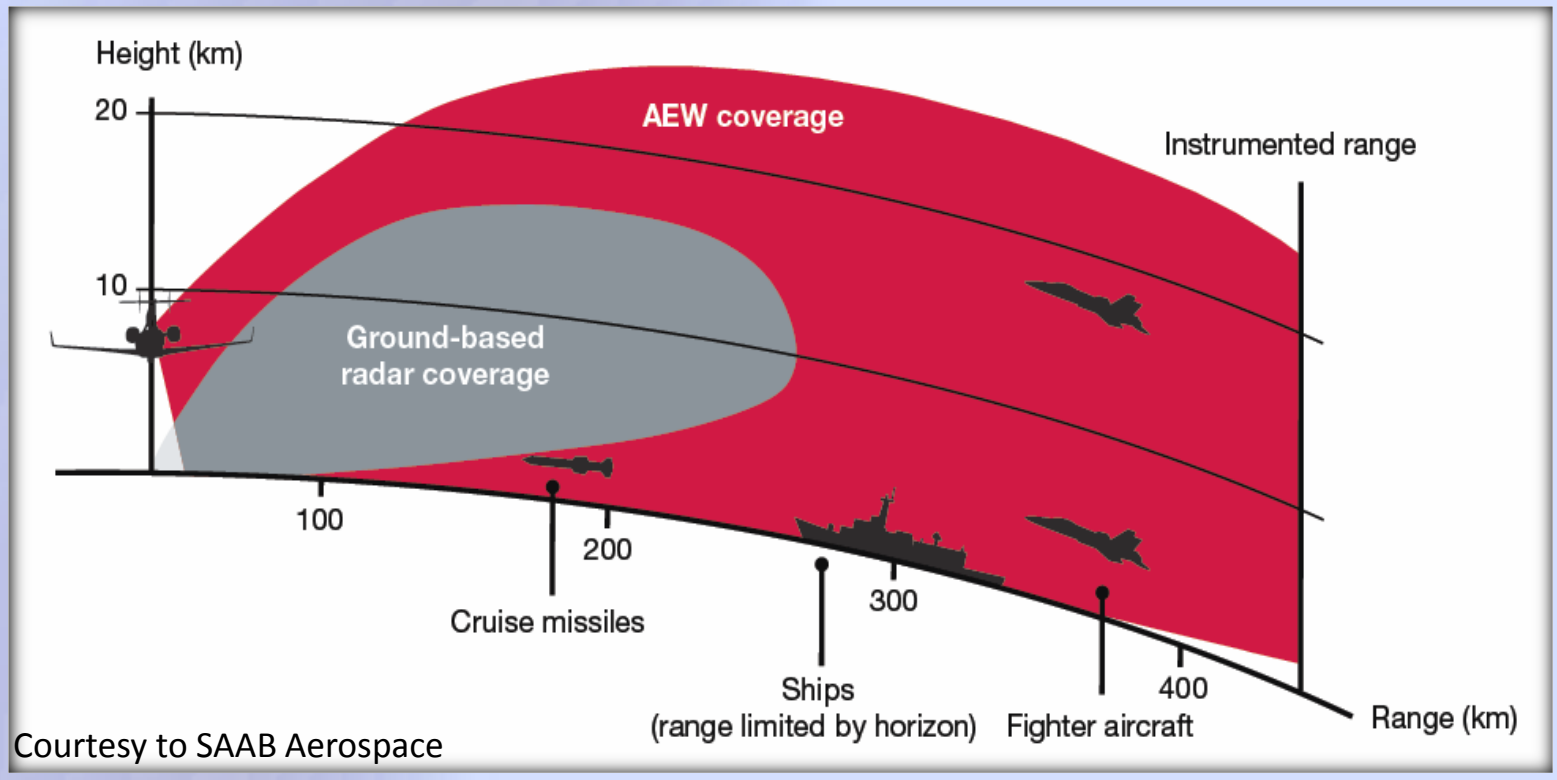


Section 1:

Introduction

Airborne Early Warning and Control (AEW&C)

The baseline of a AEW&C platform is to put a surveillance radar at <u>high altitude</u> in order to have an high surveyed area



Courtesy to SAAB Aerospace

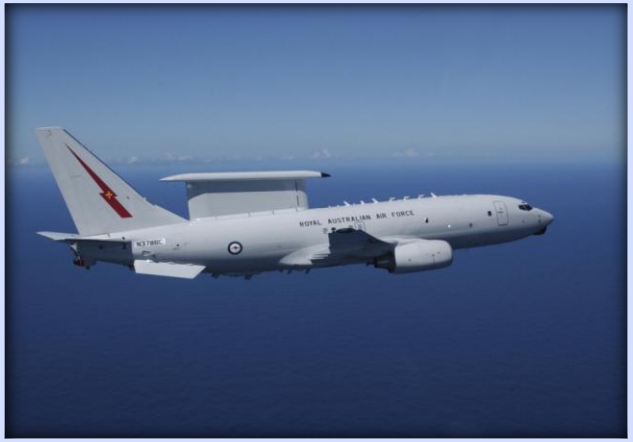
Two Kind of platform performing AEW&C missions: 1) Turbofan Airliners

Strategy to reach high altitude = > using turbofan engined platform

PROs	CONs
High Performances (range, altitude, speed)	High operating and acquisition costs

“ Boeing E-767 AWACS ”

- Service ceiling, 12.200 m
- Platform, 767-200
- AN/APY-2 radar
- 2x Turbofan engine, 276 kN



“ Boeing 737 AEW&C ”

- Service ceiling, 12.500 m
- Platform, 737-700
- ESSD MESA radar
- 2 x Turbofan engine, 121 kN

Two Kind of platform performing AEW&C missions: 2) Regional Turboprop

Strategy to reach high altitude => using turboprop platform with high power to weight ratio engines of 0,20-0,26 KW/Kg (typical values are 0,16-0,17 KW/Kg)

PROs	CONs
Lower operating costs than turbofan platforms	Higher fuel consumption than conventional turboprop platform

" SAAB 2000 AEW&C"

- Service ceiling, 9.450 m
- OEW, 14.500 kg
- MTOW, 23.000 kg
- 2x Rolls Royce turboprop, 3096 KW

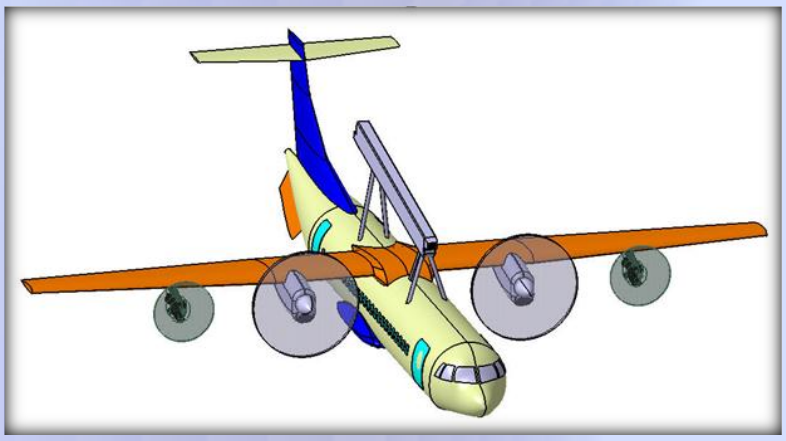
"SAAB 340 AEW&C"

- Service ceiling, 9.450 m
- OEW, 8140 kg
- MTOW, 13.155 kg
- 2x Rolls Royce turboprop, 1305 KW

Proposed Solution :
Regional Turboprop aircraft with auxiliary diesel power unit*

Strategy to reach high altitude:
Assuring a part of the power to be constant with altitude by installing turbocharged diesel auxiliary engines

PROs	CONs
Part of power generated by diesel engines with lower specific fuel consumption than turboprop	Installation of supplementary engines
Similar performances to AEW&C turboprop at lower fuel consumption	Aerodynamic Drag increase



"Diesel Turboprop AEW&C"

- Service ceiling, 9.480 m
- OEW, 12.950 kg
- MTOW, 22.000 kg
- 2x Turboprop, 1850 KW
- 2x Diesel engine, 183 KW (until 10 Km altitude)

*Considered engines are on development for UAS-MALE application

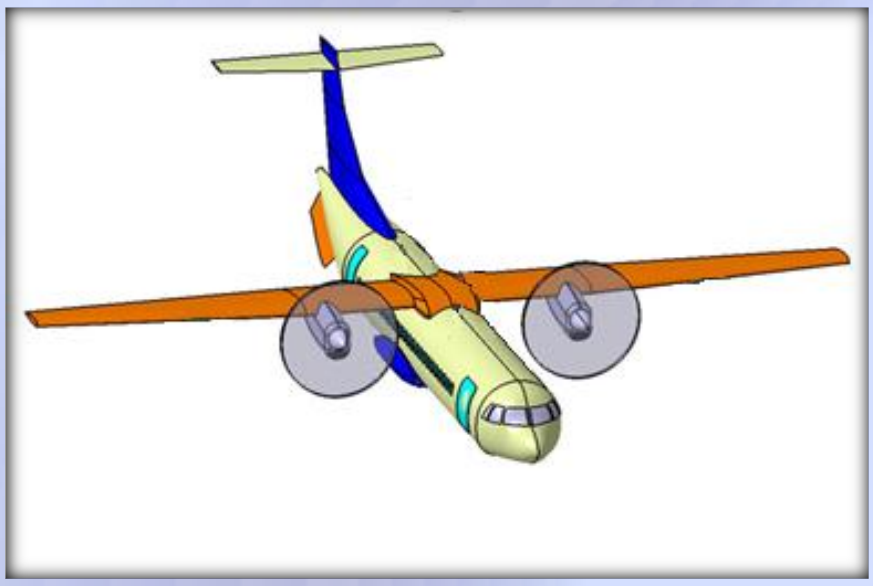
Section 2:

Conversion Issues

Conversion issues:
Platform choice

Basic platform

Turboprop aircraft for regional transportation purposes



"Regional Turboprop"

- Service ceiling, 8138 m
- OEW, 12.950 kg
- MTOW, 22.000 kg
- 2x Turboprop, 1850 KW

Conversion issues:
Radar antenna positioning against fuselage

ERIEYE AEW&C Radar system

- AESA technolgy
- Length 9,7 m
- Weight 1300 Kg
- Power absorption 60 KVA*

Distance to fuselage

Antenna height has to assure a sight angle of about 7° on unloaded wing

→ **Mean Distance to fuselage = 1,36 m**

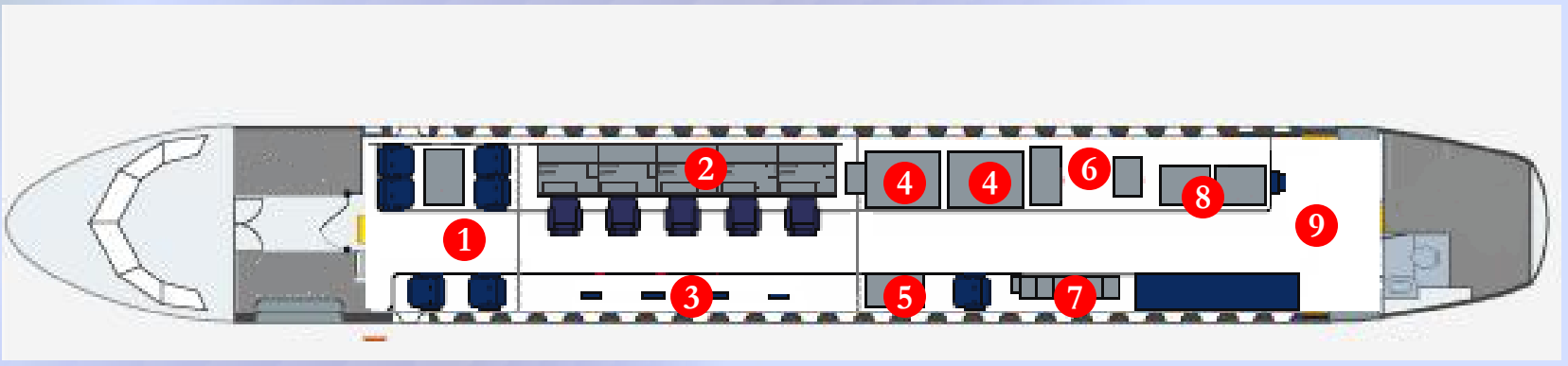
Inclination Angle

Antenna has to be parallel to horizon on flight

→ **Inclination angle to fuselage = 9,6°**

* Estimated value

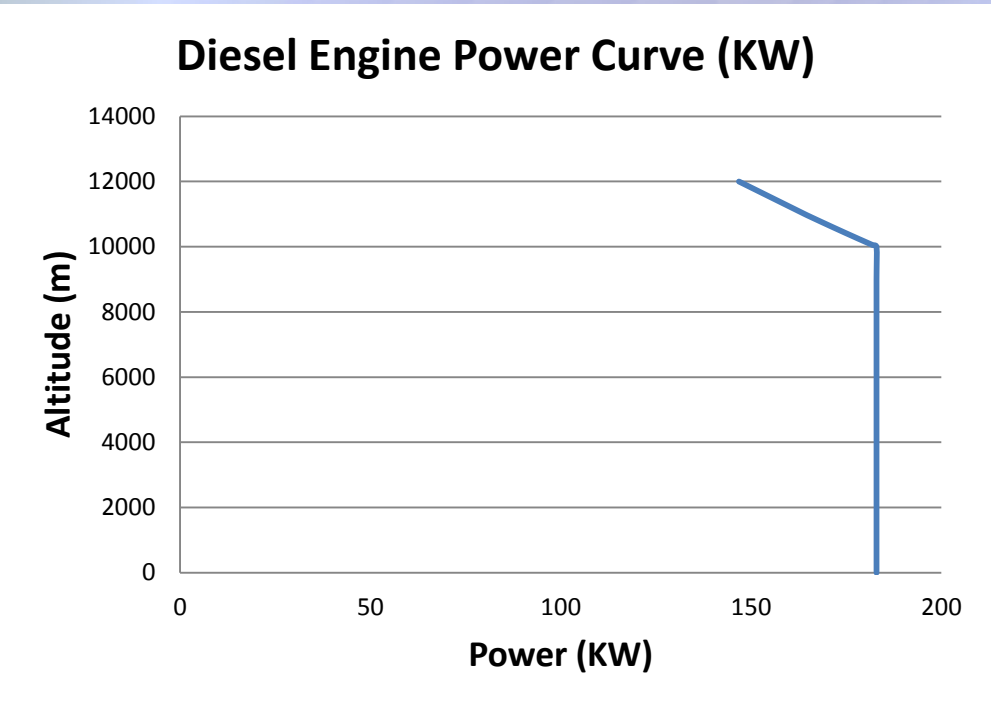
Conversion issues:
AEW&C interior systems accommodation



1. Rest Area
2. Mission operator console
3. Folding seats
4. Auxiliary fuel tank
5. Electronic Warfare equipment
6. ERIEYE equipments
7. ERIEYE power units
8. Communication rack
9. Cargo and Galley

Conversion issues:
Diesel Engine Installation

Diesel Specific fuel consumption : 231 gr/KW h
A typical value for turboprop engine is 275 gr/KW h (+ 19%)



Diesel Engine Features:

- Developed for UAS-MALE application
- Turbocharged engine
- Capacity : 2400 cc
- Power : 183 KW until 10 Km
- Engine Weight : 330 Kg
- Nacelle Weight : 42 Kg

Installation facts	
Starter/generator	20 Kg
Pylon	18 Kg
Pipe and electrical lines	40 Kg

Conversion issues:
Electrical Power supply

Electrical Power Requirements	Available Electrical Power
▪ AEW&C Erieye Radar System Power Absorption = 60 KVA*	▪ Typical regional turboprop platform are equipped with two 20 KVA class generators ▪ Diesel engines are equipped with 10 KW class starter/generators

Regional Turboprop electrical power system is not sufficient in order to supply power to AEW&C system

Possible solutions are:

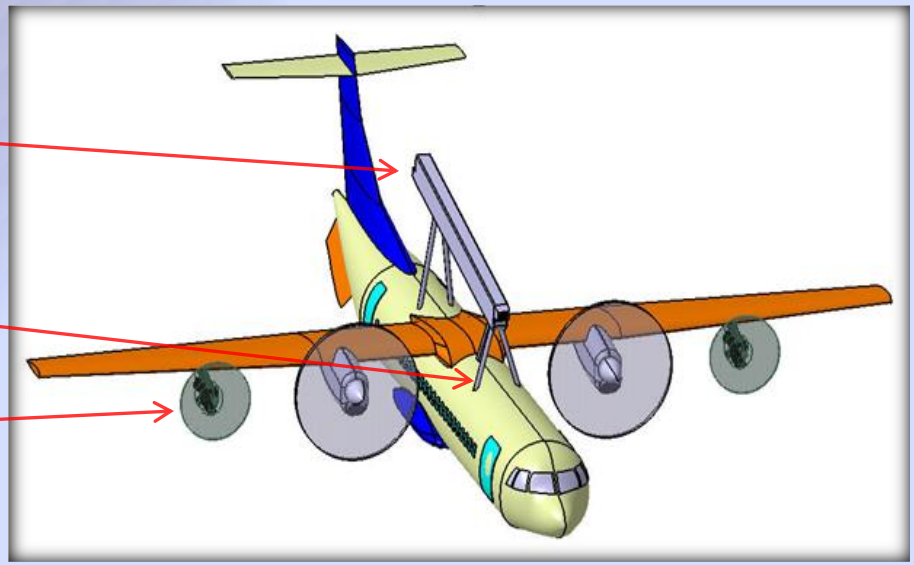
- Installing 40 KVA class generators instead of 20 KVA class generators
- Extracting power from APU during flight

* Estimated value

Conversion issues:
Zero-Lift Drag Coefficient increase

The conversion to a AEW&C platform causes the increase of zero-lift drag coefficient due to:

- **Radar antenna**
- **Pylons**
- **New Diesel Engine**



$$CD_{0_{AEW\&C}} = CD_{0_{Base}} + \Delta CD_0$$

Conversion issues:

*Aerodynamic Drag break-down**

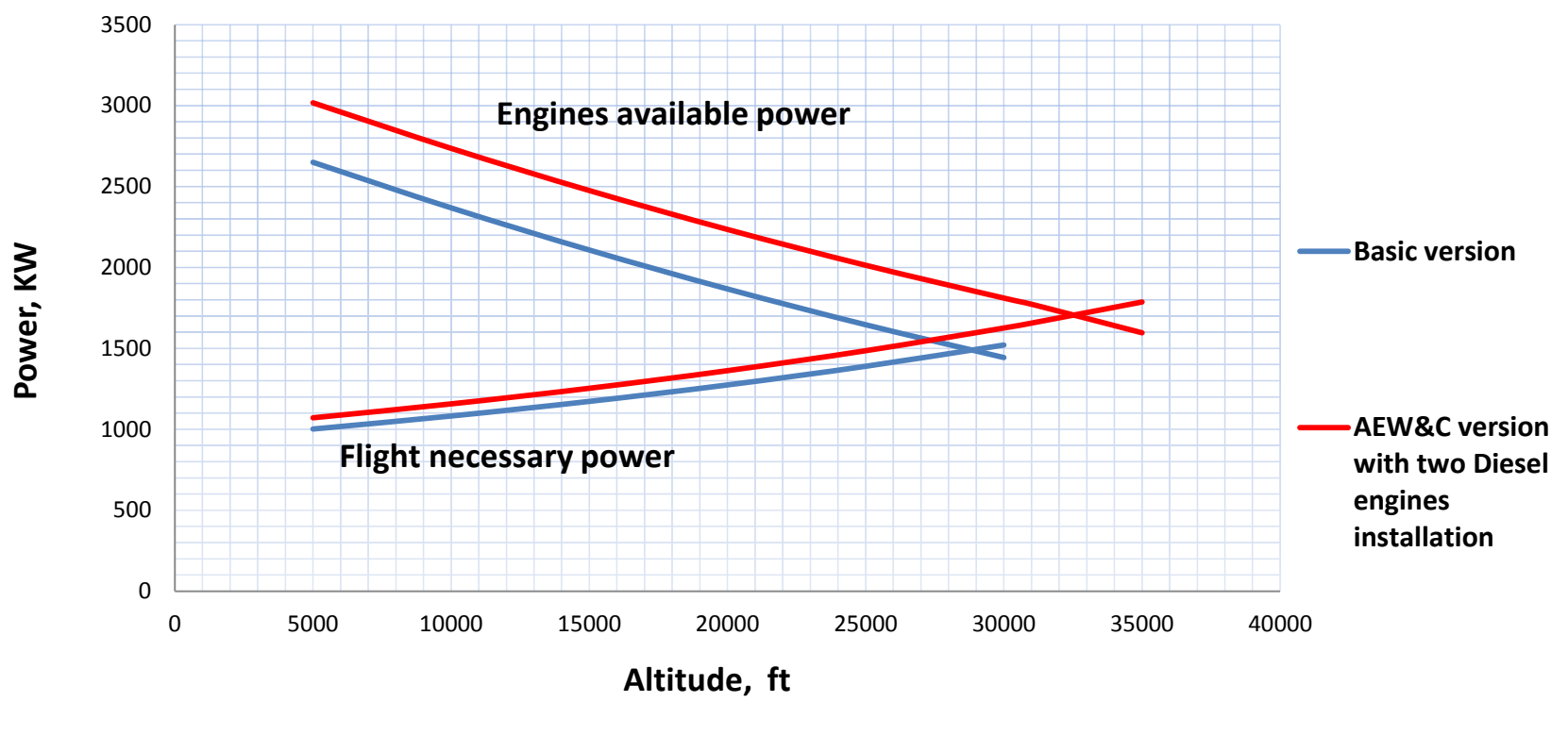
	CD_0	
Fuselage	0,008053	$CD_{0_{base}} = 0{,}027403$
Wing	0,014	
Horizontal Tail	0,0008347	
Vertical Tail	0,001315	
Engine Nacelles	0,0032	
Radar antenna	0,00254	$\Delta CD_0 = 0{,}0084$ (+ 31%)
Pylons (x5)	0,00195	
Diesel Engine Nacelles	0,00150	
Interferences	0,00065	

$$CD_{0_{AEW\&C}} = 0{,}03580$$

*All CD's are normalized toward wing surface S

Section 3:
Performance Analysis

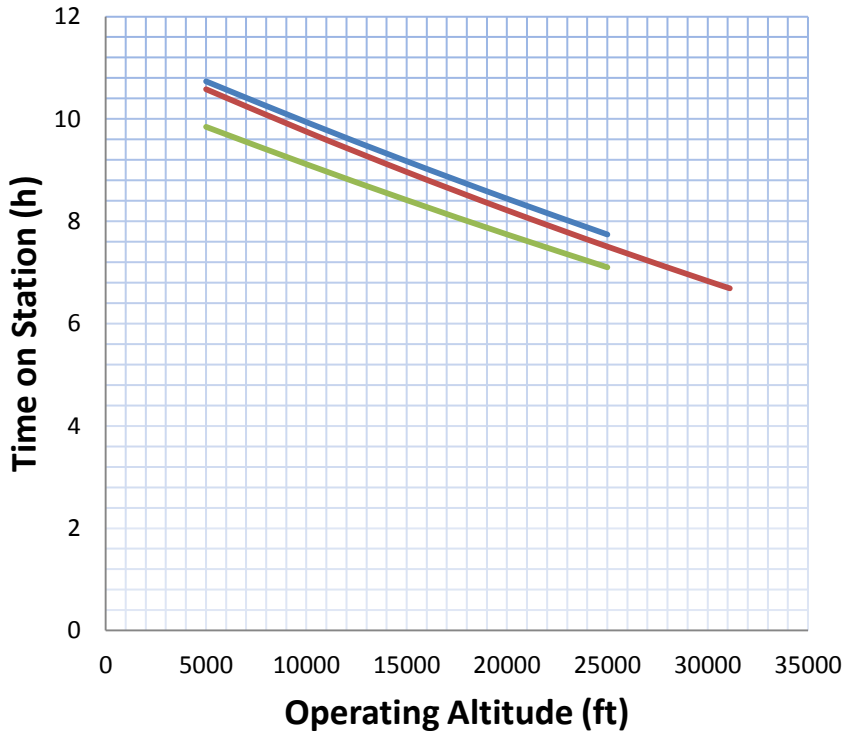
Performance Analysis:
Service Ceiling



	Basic platform	Diesel Turboprop AEW&C	
Absolute Ceiling	28200 ft (8595m)	32680 ft (9960 m)	+16%
Service Ceiling	26700 ft (8138m)	31100 ft (9480 m)	+16%

Performance Analysis: *Endurance*

Mission Profile	
Radius	250 Km
Fuel Reserve	45 min at 5000 ft



	Basic platform	AEW&C version without Diesel	Diesel Turboprop AEW&C
Drag increment (%)	+ 0 %	+ 25%	+ 31 %
Time on Station (25000 ft)	7,7 h	7 h (- 10 %)	7,5 h (- 2,8%)
Time on Station (30000 ft)	N/A	N/A	6,8 h

Weight Break-down : *OEW changes due to conversion*

OEW_{basic} = 12950 Kg	
- 2 hostess	- 140 Kg
- 72 seats	- 1080 Kg
+ 2 Diesel Engines	+ 660 Kg
+ 2 Engine Nacelles	+ 84 Kg
+ 2 Starter Generators	+ 40 Kg
+ 2 Fuel Supply Systems	+ 80 Kg
+ 2 Nacelle Pylons	+ 36 Kg
+ 2 Strakes Surfaces	+ 50 Kg
+ Pneumatic System for Radar Pylons De-icing	+ 40 Kg
+ Mission Crew (8)	+ 744 Kg

Payload Estimation

AEW&C system

ERIEYE Radar System	1300Kg
Mission equipments	350 Kg

Payload Weight = 1650 Kg

$OEW_{AEW\&C}$ = 13464 Kg

New weight break-down

Weight Break Down : *Fuel Tank Addition*

MTOW
22000 Kg

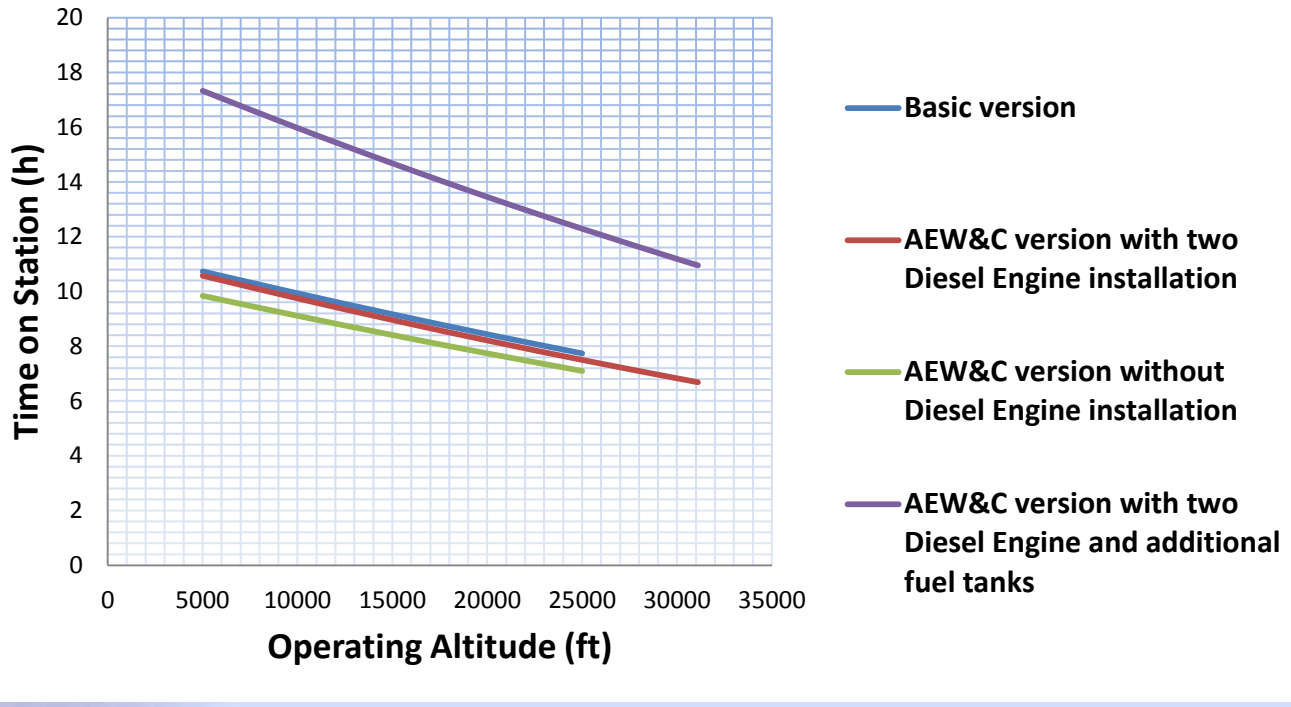
Max Fuel Weight
6886 Kg

Fuel Tanks Capacity
5000 Kg

It is possible to add a Fuel Tank of 1886 Kg

Performance Analysis: *Endurance*

Mission Profile	
Radius	250 Km
Fuel Reserve	45 min at 5000 fts



	Basic platform	AEW&C version without Diesel	Diesel Turboprop AEW&C	Diesel Turboprop AEW&C with additional fuel tanks
Drag increment (%)	+ 0 %	+ 25%	+ 31 %	+31 %
Time on Station (25000 ft)	7,7 h	7 h (- 10%)	7,5 h (- 2,7%)	12,3 (+60%)
Time on Station (30000 ft)	N/A	N/A	6,8 h	11,2 h (+65 %)

Section 4:

Effectiveness-Cost Analysis

Effectiveness analysis: *Methodology*

Global effectiveness of a platform

$$U(x) = \frac{1}{K}\left\{\prod_{i}^{n}\left[Ka_i U_i(x) + 1\right] - 1\right\}$$

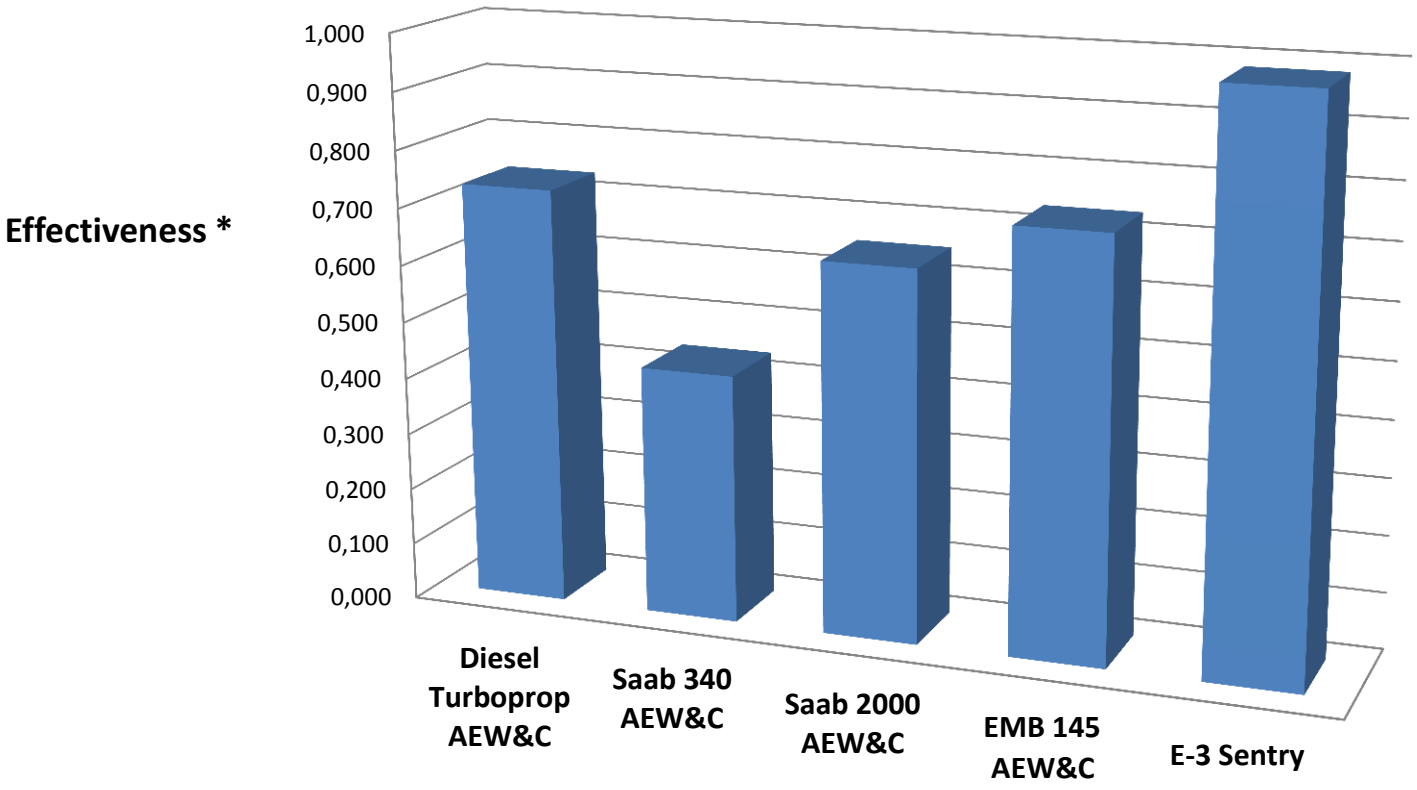
Normalization constant

Relative importance coefficients

Effectiveness of a single parameter

	Diesel AEW&C Turboprop	Saab 340 AEW&C	Saab 2000 AEW&C	EMB 145 AEW&C	E3 - Sentry
Max Endurance	12,5 h	7 h	9 h	8 h	11,4 h
Max Range	2261 nm	937 nm	2000 nm	2000 nm	5000 nm
Service Ceiling	9480 m	9450 m	9450 m	11275 m	11855 m
Radar System	Erieye	Erieye	Erieye	Erieye	AN/APY-2
Crew	10	7	10	10	17
TO Field Length (ISA,SL,MTOW)	1223 m	1285 m	1220 m	1970 m	3054 m
Max Cruise Speed	511 Km/h	522 Km/h	660 Km/h	833 km/h	973 Km/h
Cabin Floor	41 m^2	18 m^2	28 m^2	26 m^2	106 m^2

Effectiveness analysis: *Results*

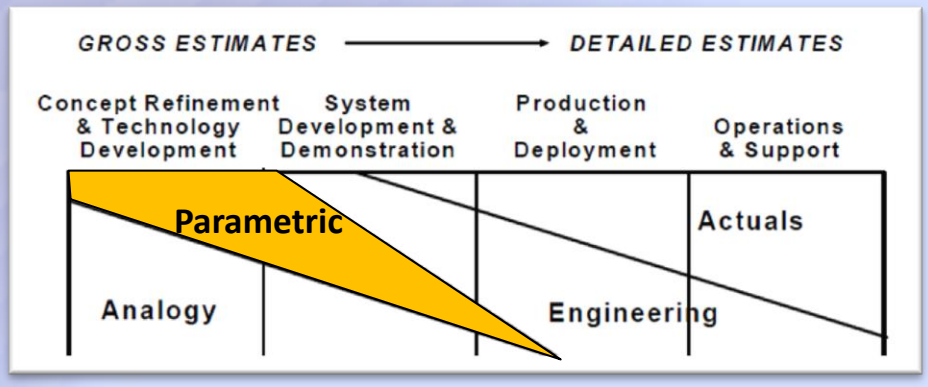


Diesel Turboprop AEW&C	Saab 340 AEW&C	Saab 2000 AEW&C	EMB 145 AEW&C	E-3 Sentry
0,734	0,438	0,650	0,734	0,982

* Normalized Values

Cost analysis: *Methodology*

A homemade parametric/statistical model has been used to estimate aircraft maintenance cost. The MMH/FH parameter is the main model cost driver.



Operating & Support Cost Items	
Cash DOC	**Direct personnel (crew, maintainers) , consumable material**
	Spares and depot maintenance
	Fuel and lubricants (POL)
	Satcom service
DOC	**Above items and depreciation**

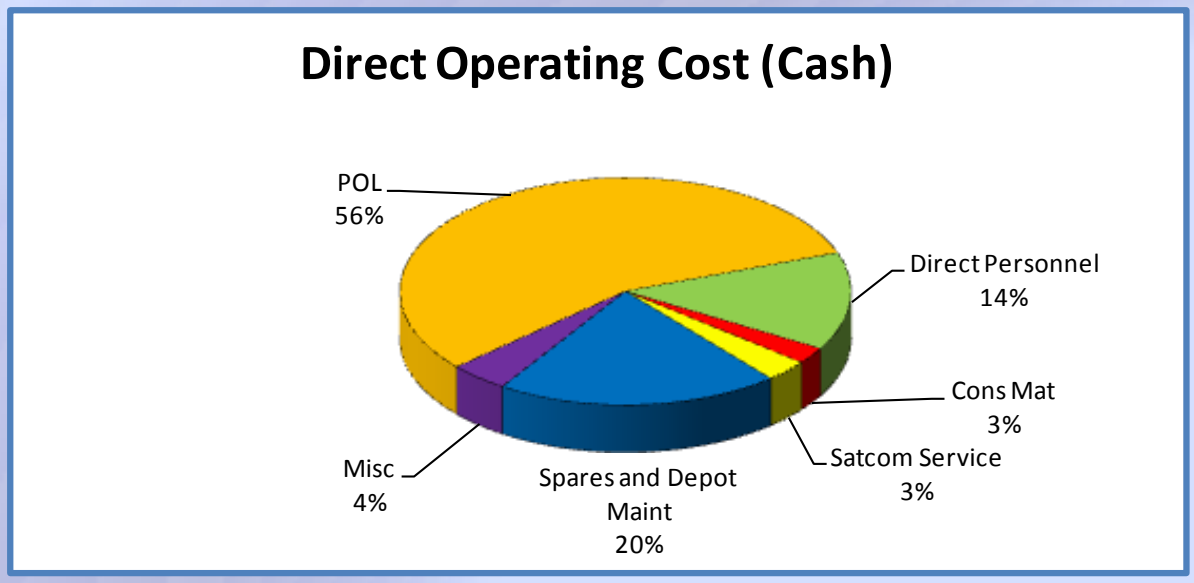
→ Parametric model

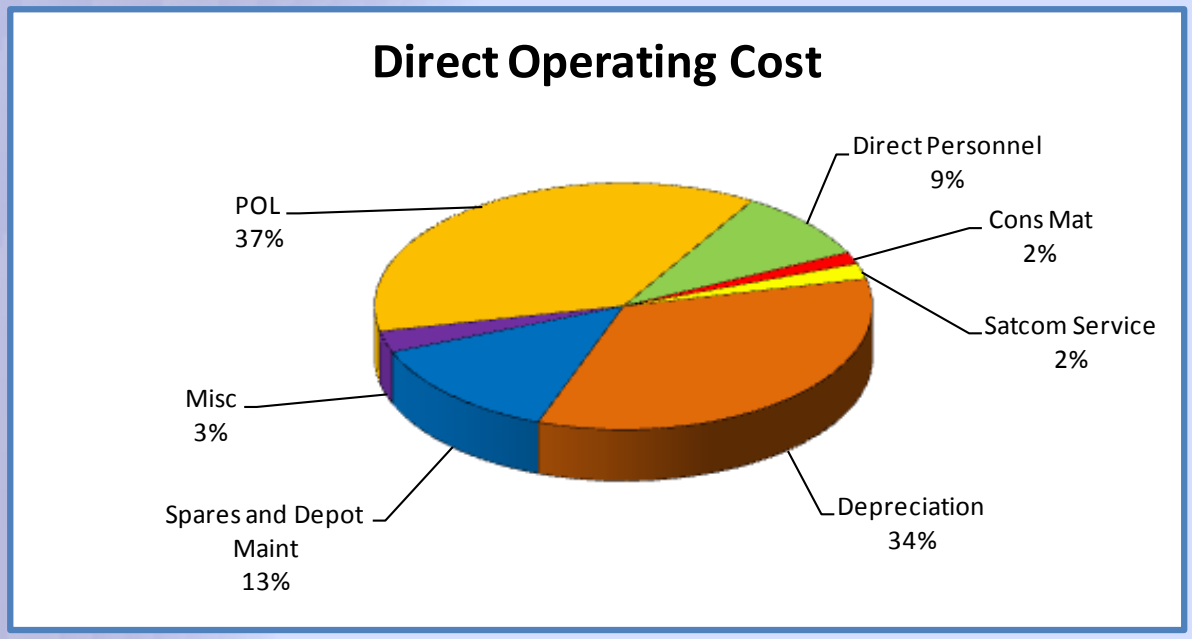
→ Fuel weight * fuel cost

→ 20% Mission time * SATCOM cost/hour

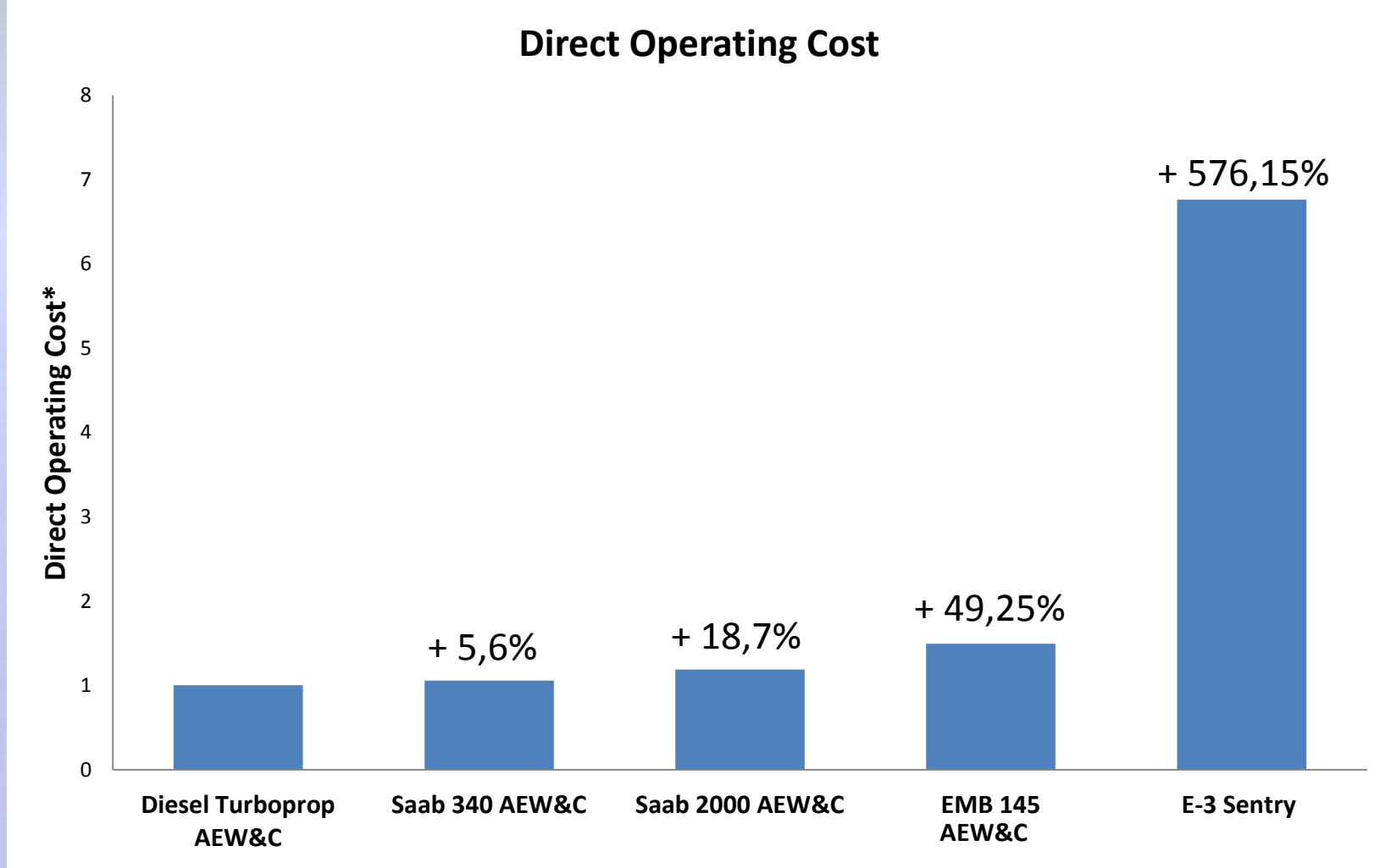
→ **Depreciation**, typical civil DOC item, has been calculated to take in to account the aircraft acquisition cost

Cost analysis: *Diesel Turboprop AEW&C Results*



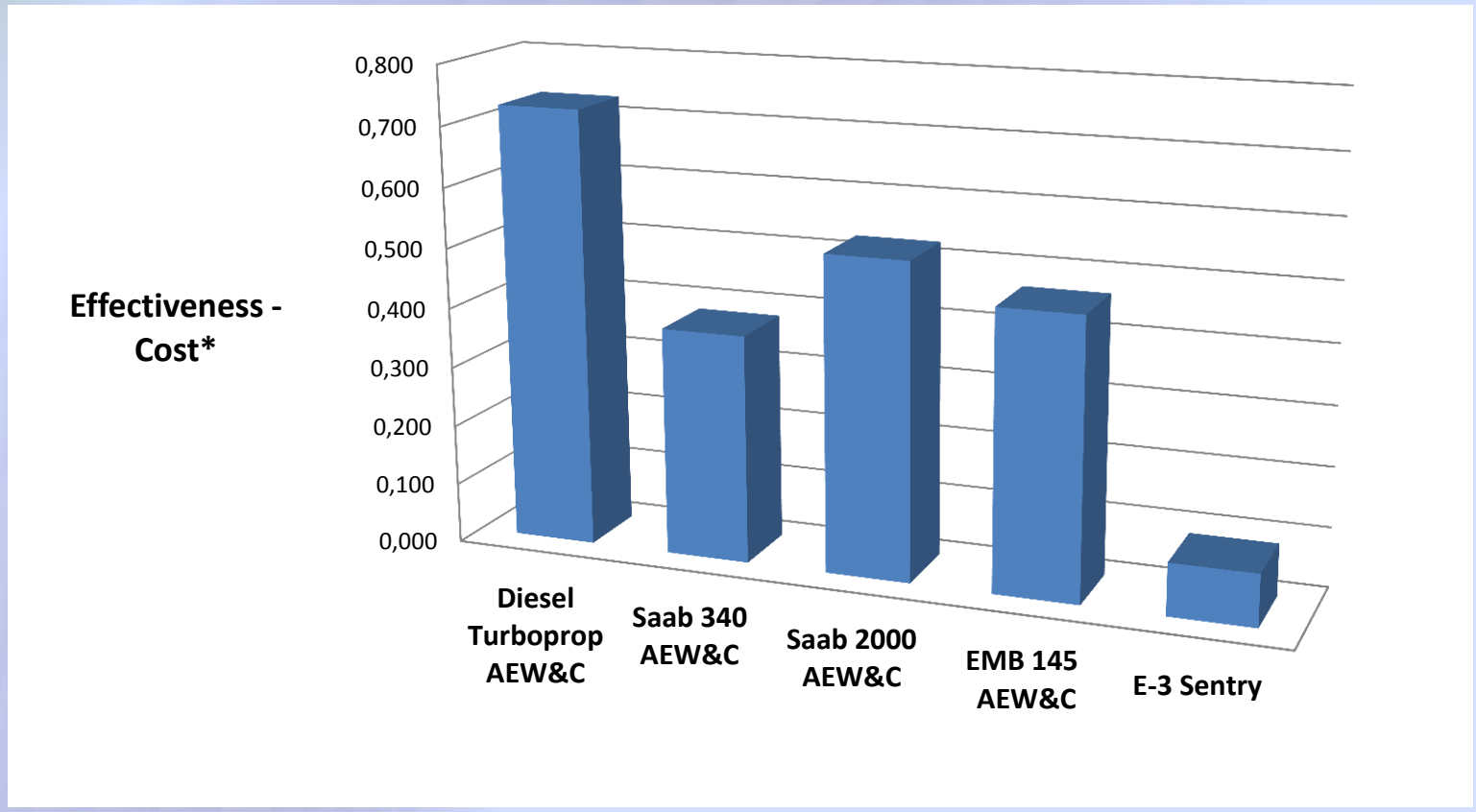


Cost analysis: *Comparisons*



* Normalized Values

Effectiveness - Cost Analysis : *Results*



Diesel Turboprop AEW&C	Saab 340 AEW&C	Saab 2000 AEW&C	EMB 145 AEW&C	E-3 Sentry
0,729	0,381	0,527	0,466	0,088

* Normalized Values

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Thank you all indeed

Any question?