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The 7th European Aeronautics Days

Clean Sky Technology Evaluator
Environmental Performance Assessment of Rotorcraft

by

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Slides courtesy of:
AH, AW, CIRA, DRL, SISW, NLR, ONERA, THALES, TURBOMECA

Main Topics

Main Topics

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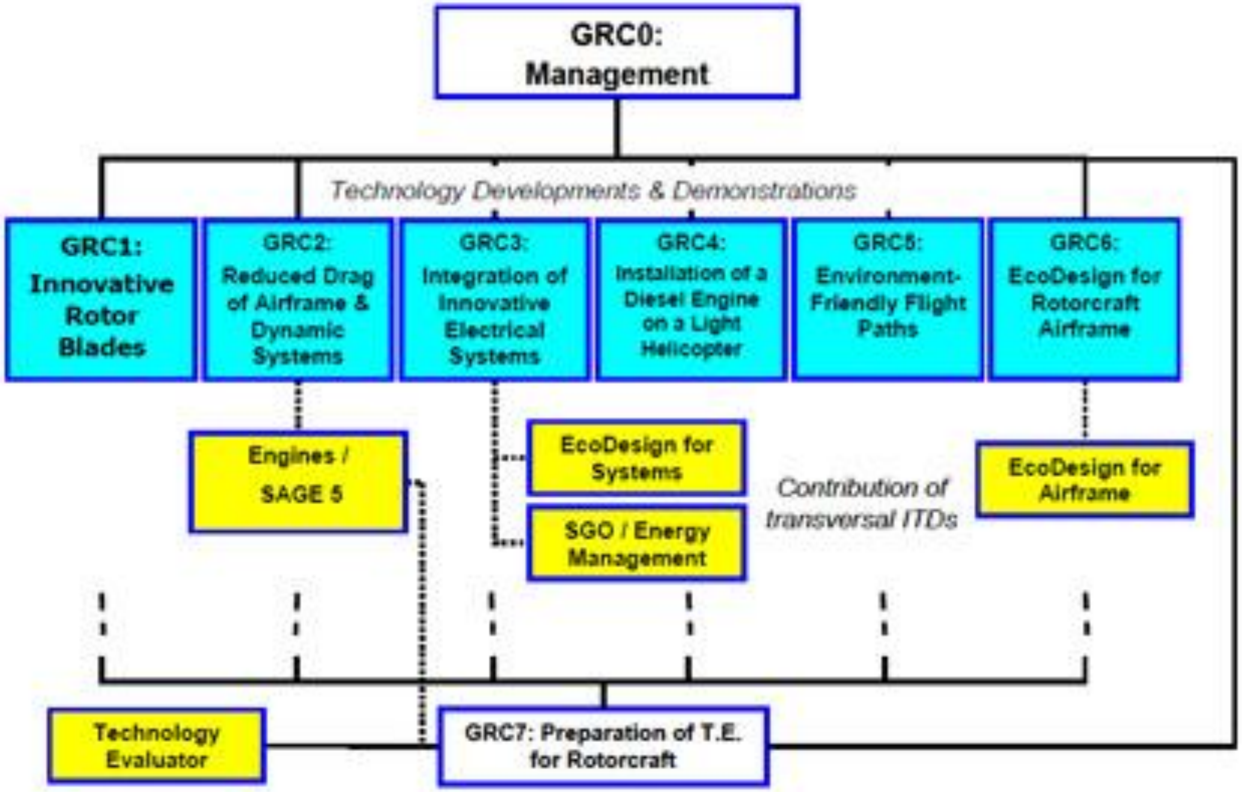
Main Objective

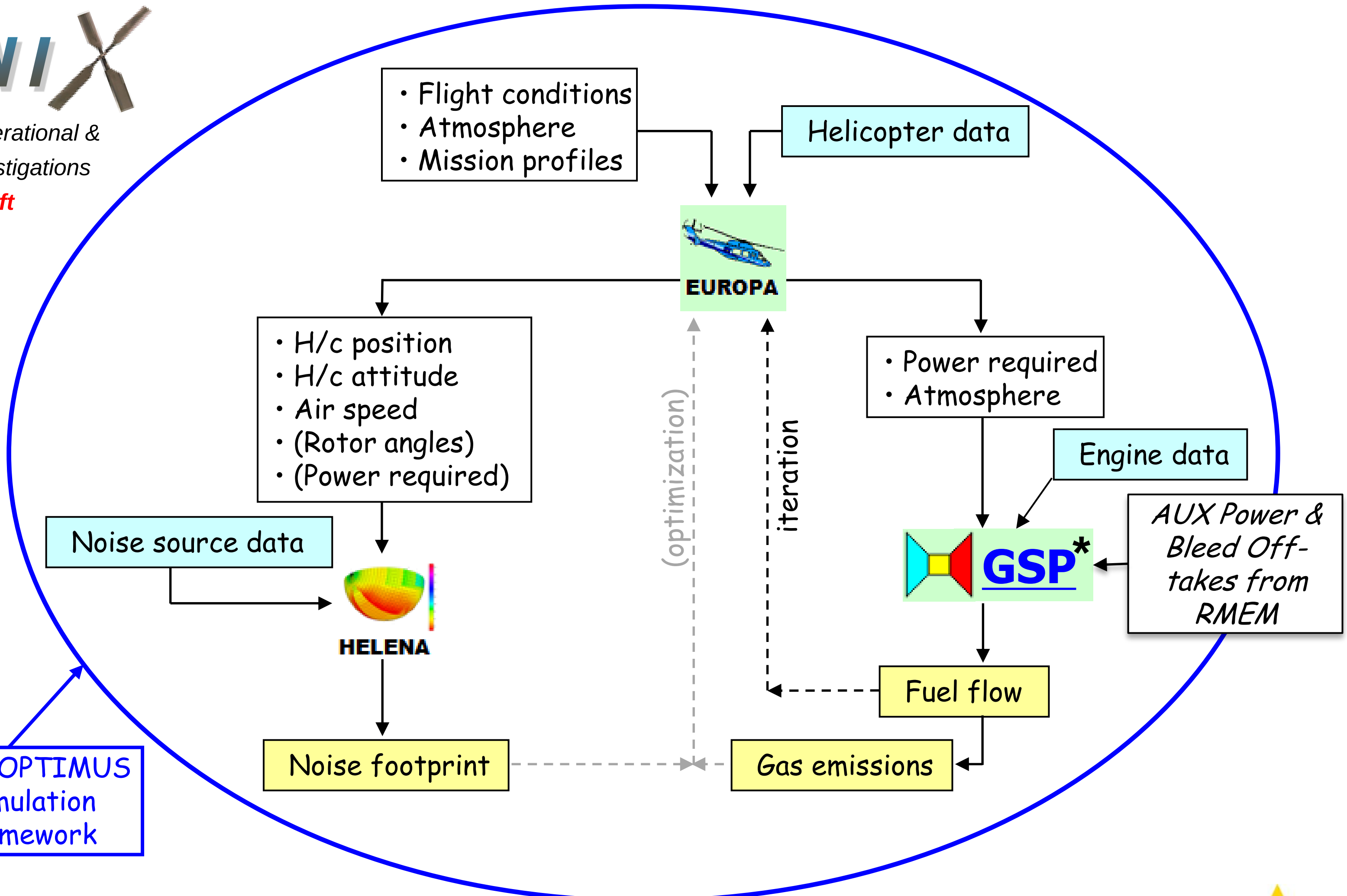
- Predict the environmental impact of all GRC technologies on the rotorcraft fleet of 2020 and beyond
    - Simulation framework developed by GRC7 participants (NLR, SISW, AH, AW, ONERA, DLR, PZL, CIRA) with input and support by TE partners (CU, NLR, ONERA, DLR, CIRA, THALES) and SAGE ITD (TM)
    - Special 'Research Cooperation Agreement' in place between GRC(7), CU(TE) & TM(SAGE 5)
    - Ability to run rotorcraft model trade-off studies (GRC7) and environmental impact assessments (TE)

Main Topics

Introduction
TE Interface with GRC7



Introduction
Phoenix Architectural Overview



*GSP code verified by TM, gradually being replaced by TM's engine decks

Introduction
Rotorcraft Simulation Tools

- EUROPA
  - Flight mechanics code, designed to calculate helicopter steady state (trim) and dynamic (manoeuvre) performance, developed and validated in the EU projects RESPECT [6] and NICETRIP (tilt rotor version) [3]

- HELENA
  - Developed within the FRIENDCOPTER [2] project and is capable of computing and generating noise footprints on the ground starting from experimental or numerical (CFD) based helicopter noise databases [1]

- GSP
  - In-house tool developed by NLR [4] to simulate gas turbine thermodynamic cycles for engine performance (fuel flow, power) and exhaust gas emissions

Introduction
Rotorcraft Simulation Tools

- TM engine decks
  - Provide turboshaft engine performance and emissions calculations

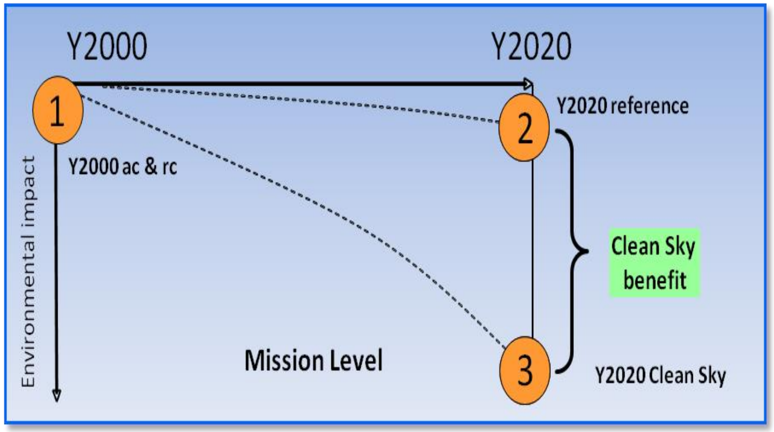
- Rotorcraft Mission Energy Management (RMEM) module
  - Models rotorcraft sub-systems following a bottom-up approach
  - Incorporates physics based, first-principles methods
  - Increases confidence in the modelling of sub-system power and bleed off-take requirements
  - Improved CO_2 and NO_x calculations

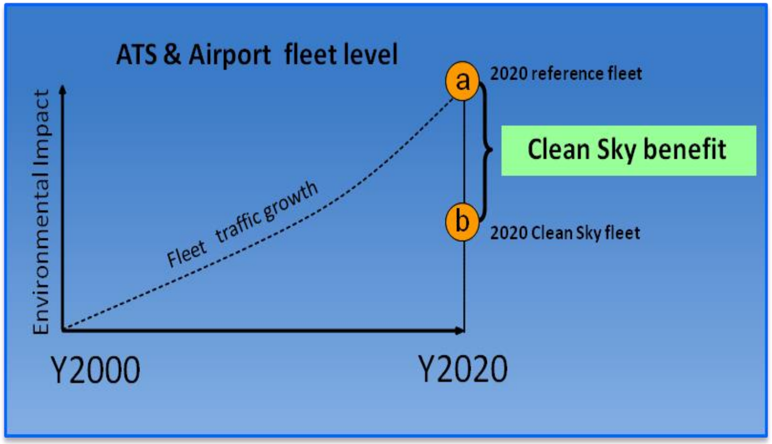
- OPTIMUS
  - Process integration simulation framework, provided by SISW with the aim of establishing a proper workflow between EUROPA, GSP and HELENA [5]. Provision of federation mechanism to include other codes
  - Simulation framework incorporates a GUI (provided by SISW)

Introduction
RC Classes & Assessments

- In the context of the TE assessments, 5 different classes have been defined
  - Single Engine Light (SEL) with MTOW ≤ 4 metric tons
  - High Compression Engine (HCE) with MTOW ≤ 4 metric tons
  - Twin Engine Light (TEL) with MTOW ≤ 4 metric tons
  - Twin Engine Medium (TEM) with 4 ≤ MTOW ≤ 8 metric tons
  - Twin Engine Heavy (TEH) with MTOW > 8 metric tons

- 3 Assessment Levels; Mission / Airport / ATS





Introduction
Mission Scenarios

- Definition of the operational flight trajectories for the 5 RC classes

SEL_U1	Passenger	FE & PA - 5 x 2 missions
HCE	Police	FE & PA - 2 x 2 missions
	Passenger	FE & PA - 1 x 2 missions
	Training	FE only - 2 missions
TEL_U1	EMS	FE & PA - 5 x 2 missions
	Police	FE & PA - 5 x 2 missions
TEM	SAR	FE & PA - 5 x 2 missions
	Civil Utility	FE & PA - 5 x 2 missions
TEH_U1	Oil&Gas	FE only - 3 missions x 10

Delivered & being assessed

FE: Fuel Economy, PA: Population Avoidance

Introduction
Mission Scenarios

- Number of missions represents the operational traffic of RC flights over 3 major cities :
  - Rome (EMS, Civil Utility)
  - Hannover (Passenger, Police and Civil Training)
  - Stockholm (SAR, Police)

- Den Helder heliport used for the Oil & Gas missions to represent a typical helicopter traffic of the North Sea Continental Shelf
  http://www.chc.ca/OilandGas/FlightSchedule/Pages/default.aspx

Main Topics

1 Main Objective

2 Introduction

3 Methodology

4 Environmental Assessment Examples

5 Other Collaborative Work

6 Conclusions

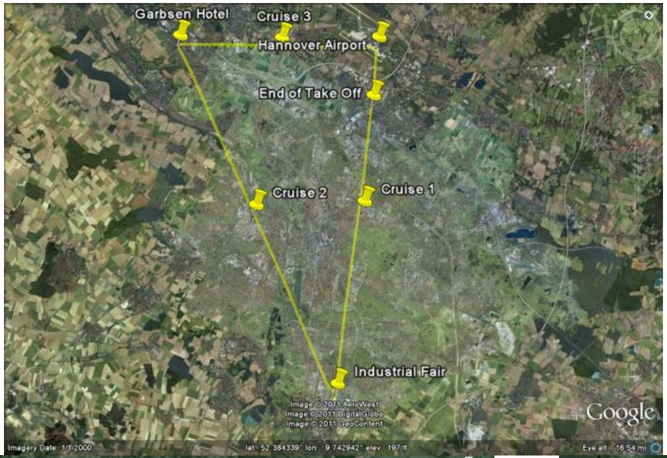
Methodology
Example Scenario Definition

Passenger Missions SEL_U1

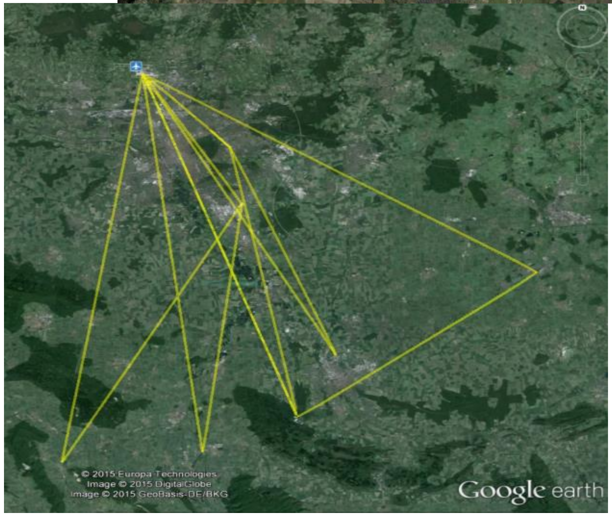
Fuel Economy

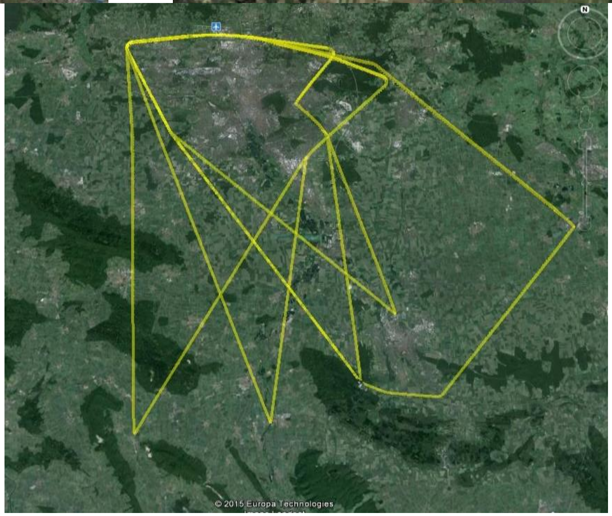
Population Avoidance

Mission Level



Airport Level



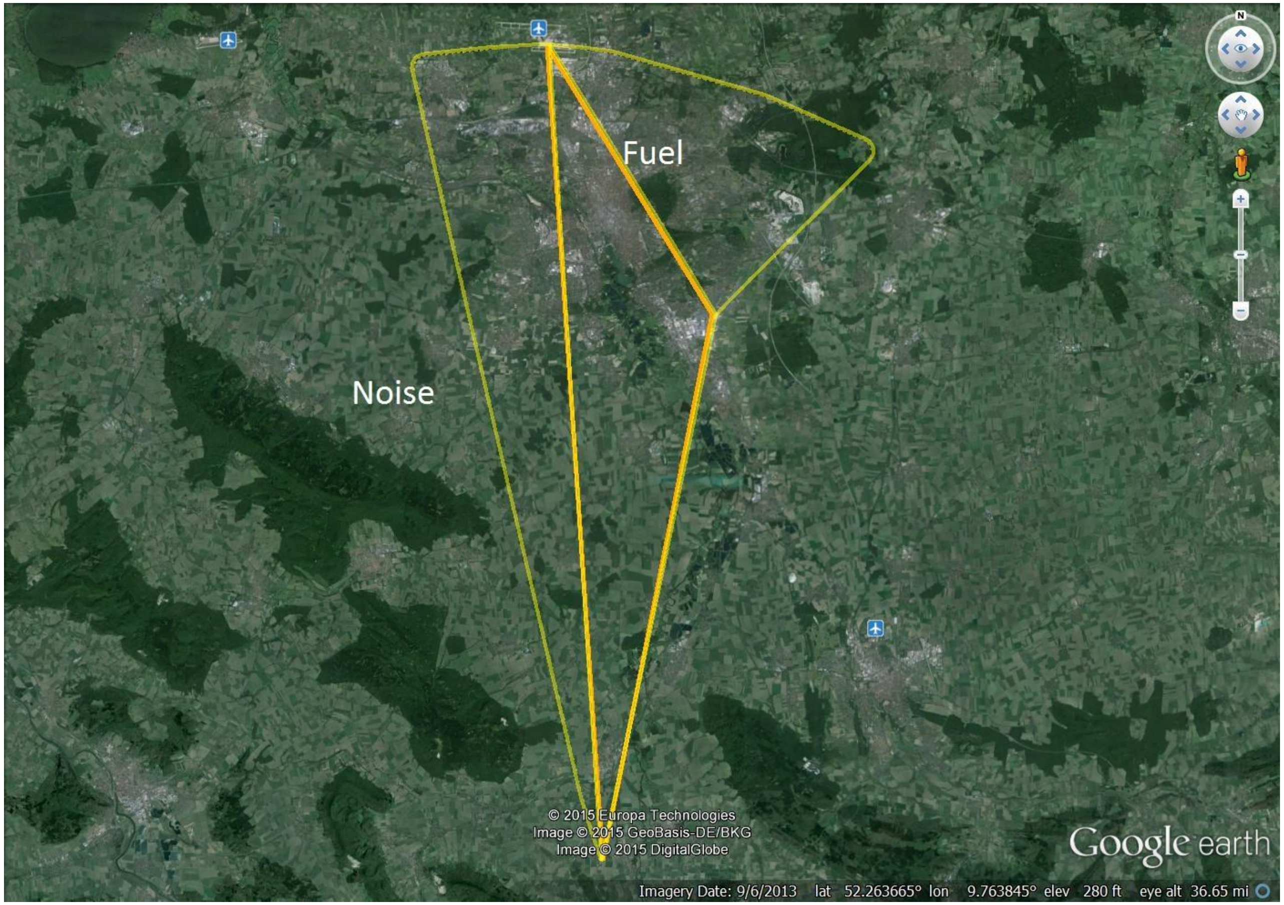


Methodology
Example Scenario Definition

Passenger Missions SEL_U1

Fuel Economy & Population Avoidance

ATS Level



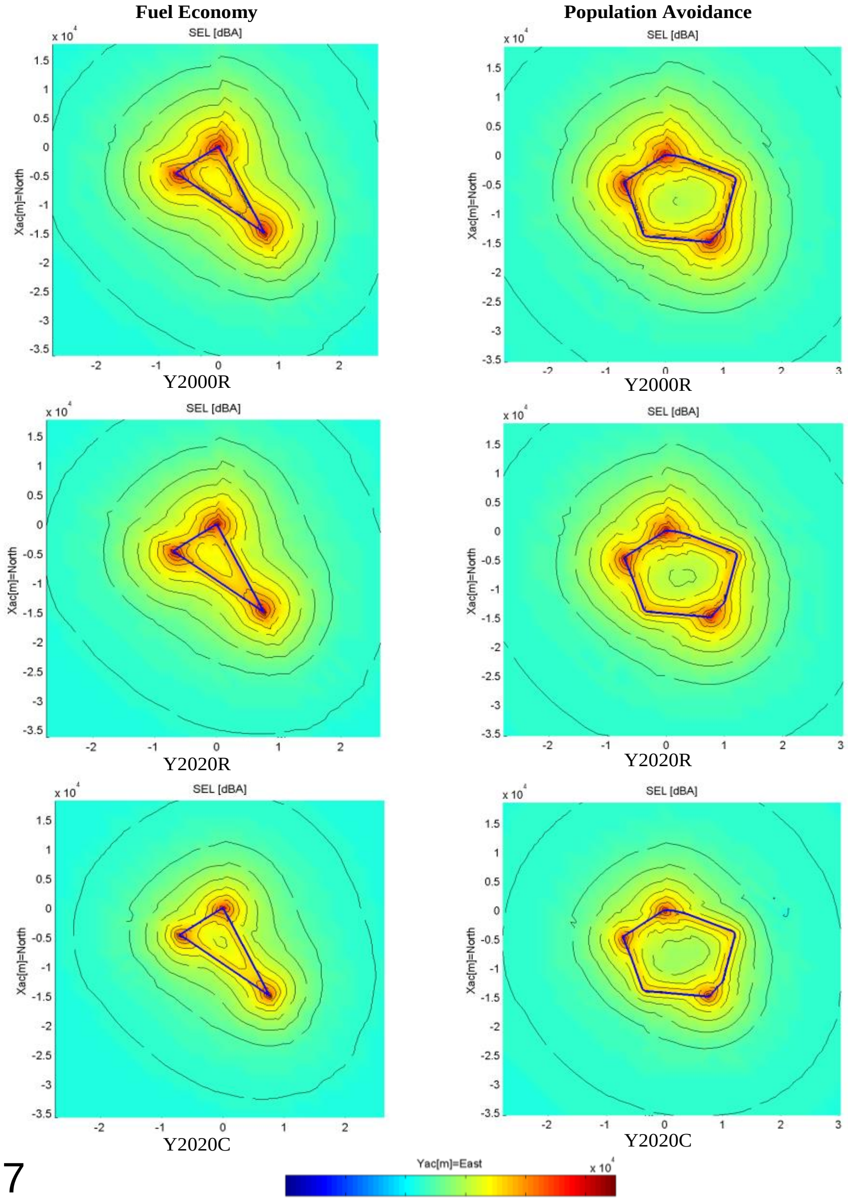
Methodology
Example Operational Procedure

- The operational procedures for all the missions have been derived in conjunction with EHOC's input and recommendations

- Typical procedure for a SEL_U1 helicopter on a Passenger mission:

1.The helicopter starts engine and rotors on the ground at the helipad
2. The helicopter remains in idle for 5 minutes
3. The helicopter transits to the main runway in ground effect and awaits take off clearance
4. The helicopter lifts into hover
5. The helicopter climbs to 1500 ft AGL at 80 knots
6. The helicopter transits to the location of the passenger-executive pick up point at 120 knots
7. The helicopter hovers whilst pilot positions for landing
8. The helicopter lands at the passenger-executive pick up point and the passenger(s) get on board
9. The helicopter awaits for take-off clearance
10. The helicopter lifts into hover
11. The helicopter climbs to 1500 ft AGL at 80 knots and heads towards the designated passenger drop-off zone at 120 knots
12. The helicopter lands at the designated drop off zone and the passengers exit the aircraft
13. The helicopter lifts into hover
14. The helicopter climbs to 1000 ft AGL at 80 knots and heads towards the originating heliport at 120 knots
15. The helicopter lands at the original heliport
16. The helicopter sits for 1 minute with rotors turning on the ground

Methodology
Example Assessment Process



- Performance assessments between Y2000B, Y2020R and Y2020C configurations carried out on the basis of;
  - Fuel burn
  - CO_2
  - NO_x
  - Acoustic ground footprint

Methodology
Implemented Technologies

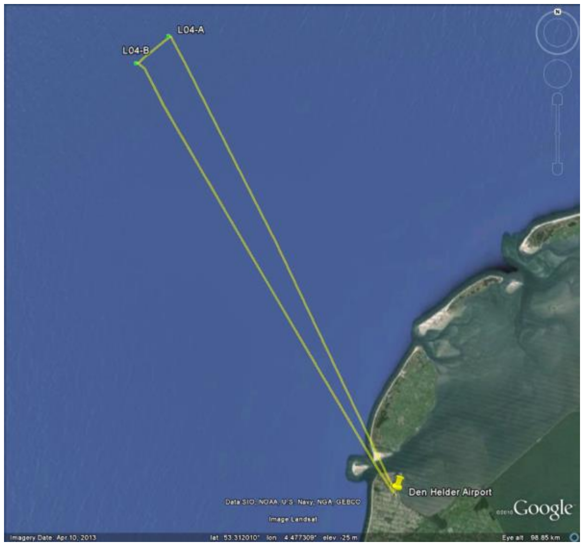
R/C	Mission	Mission Type	GRC CleanSky Benefits Applied to Y2020 Reference = Y2020 Conceptual	EUROPA Δ	HELENA Δ	ENGINE Δ
SEL	Passenger / Taxi	Noise reduction requirement < 2000ft, over densely populated area	GRC1 - Active Twist & Passive Optimized Blades	√	√	
			GRC2 - Active devices/vortex on blunt fuse, improved skids & hub cap	√		
			GRC3 - Brushless starter generator, power convertor, energy storage, distribution & recovery, electromechanical actuators, piezo actuators	√		
			SAGE ITD - CO_2 and NO_x reduction applied to GSP engine model			√ (GSP)
R/C	**Mission**	**Mission Type**	**GRC CleanSky Benefits Applied to Y2020 Reference = Y2020 Conceptual**	**EUROPA Δ**	**HELENA Δ**	**ENGINE Δ**
SELU1	Passenger / Taxi	Noise reduction requirement < 2000ft, over densely populated area	GRC1 - Passive Optimized Blades (no active rotor)	√	√	
			GRC2 - Active devices/vortex on blunt fuse, improved skids & hub cap	√		
			GRC3 - Brushless starter generator, power convertor, energy storage, distribution & recovery, electromechanical actuators, piezo actuators	√		
			GRC5 - Generic optimised trajectory to be updated in HELENA by GRC7 in the 2nd quarter	TBA	TBA	
			GRC6 - Thermoplastic tail, transmission shaft, roof panel, skid fairing	√		
			SAGE ITD - provision of TM engine models			√ (TM)
R/C	**Mission**	**Mission Type**	**GRC CleanSky Benefits Applied to Y2020 Reference = Y2020 Conceptual**	**EUROPA Δ**	**HELENA Δ**	**ENGINE Δ**
HCE	Long range Passenger Mission	Noise reduction requirement < 2000ft, over densely populated area	Technologies as per SELU1-C defined above			
			LMS - Engine model representing the HCE low NO_x combustion technology			√ (LMS)

Methodology
Implemented Technologies

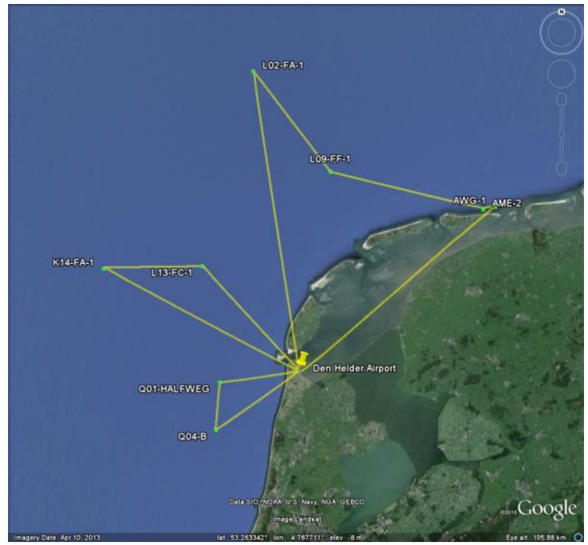
R/C	Mission	Mission Type	GRC CleanSky Benefits Applied to Y2020 Reference = Y2020 Conceptual	EUROPA Δ	HELENA Δ	ENGINE Δ
TEL & TELU1	EMS & Police	Noise reduction requirement < 2000ft, over densely populated area	GRC1 - Active Twist & Passive Optimized Blades	√	√	
			GRC2 - Active devices/vortex on blunt fuse, improved skids & hub cap	√		
			GRC3 - Brushless starter generator, power convertor, energy storage, distribution & recovery, electromechanical actuators, piezo actuators	√		
			SAGE ITD - CO_2 and NO_x reduction applied to GSP engine model			√ (GSP)
R/C	Mission	Mission Type	GRC CleanSky Benefits Applied to Y2020 Reference = Y2020 Conceptual	EUROPA Δ	HELENA Δ	ENGINE Δ
TEM	SAR & Civil Utility Fire-Sup	Noise reduction requirement < 2000ft, over densely populated area	GRC1 - Active Twist & Passive Optimized Blades	√		
			GRC2 - Active devices/vortex on blunt fuse, improved skids & hub cap	√		
			GRC3 - Brushless starter generator, power convertor, energy storage, distribution & recovery, electromechanical actuators, piezo actuators	√		
			GRC5 - Generic optimised trajectory	√	√	
			GRC6- Thermoplastic tail, transmission shaft, roof panel, skid fairing	√		
			SAGE ITD - Engine model representing the (Turbomeca) low NO_x combustion technology			√ (TM)
R/C	Mission	Mission Type	GRC CleanSky Benefits Applied to Y2020 Reference = Y2020 Conceptual	EUROPA Δ	HELENA Δ	ENGINE Δ
TEH	Oil&Gas	Performance >2000ft, no noise reduction requirement	GRC1 - AGF & Passive Optimized Blades	√		
			GRC2 - Passive shape optimization/vortex on blunt aft & improved hub cap	√		
			GRC3 - Brushless starter generator, power convertor, energy storage, distribution & recovery, electromechanical actuators, piezo actuators	√		
			GRC6 - Thermoplastic tail, transmission shaft, door & floor demonstrators	√		
			SAGE ITD - Engine model representing the (Turbomeca) low NO_x combustion technology			√ (TM)

Main Topics

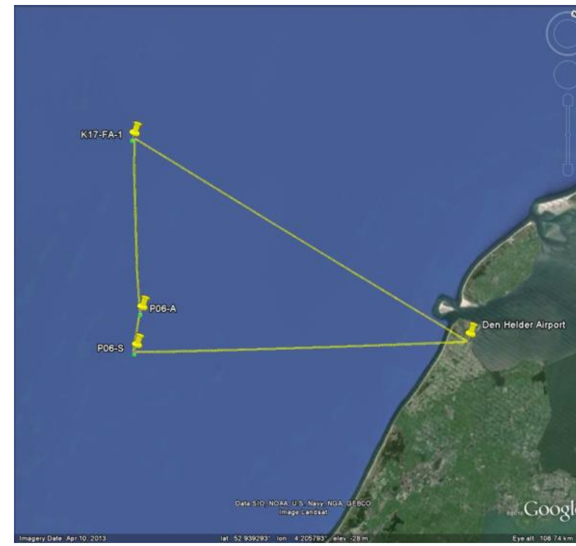
Oil & Gas Mission TEH_U1



Mission to Airport



Airport to ATS



ATS mission constructed based on the average of the heliport level missions

Environmental Assessment Example I

Operational Procedure for TEH_U1

- The operational procedures for all the missions have been derived in conjunction with EHOC’s input and recommendations

- Typical procedure for a TEH_U1 helicopter:
  1. The helicopter starts both engine(s) and rotors on the ground at the helipad
  2. The helicopter remains in idle for 5 minutes
  3. The helicopter taxis to the passenger terminal and collects 10 passengers and baggage
  4. The helicopter taxis to the main runway and awaits for take off clearance
  5. The helicopter lifts into hover
  6. The helicopter climbs to 3000 ft AGL at 80 knots.
  7. The helicopter transits at 120 knots towards the first oil off-shore platform
  8. The helicopter hovers over the oil platform where it eventually lands and unloads its payload as well as any personnel
  9. The helicopter sits for 10 minutes on the deck during passenger and baggage offloading and loading
  10. The helicopter lifts into hover with 10 passengers and baggage
  11. The helicopter climbs to 1000 ft AGL at 70 knots and heads towards the second oil off-shore platform
  12. The helicopter hovers over the oil platform where it eventually lands and unloads its payload as well as any personnel
  13. The helicopter sits for 10 minutes on the deck during passenger and baggage offloading and loading
  14. The helicopter lifts into hover with 5 passengers and baggage
  15. The helicopter climbs to 3000 ft AGL at 80 knots and heads towards the original heliport at 120 knots
  16. The helicopter lands at the original helipad
  17. The helicopter sits for 10 minute with rotors turning on the ground during unloading
  18. The helicopter taxis according to the directions provided by the ATC of the airport
  19. The helicopter taxis to the hangar and shuts down

Environmental Assessment Example I
Airport Level Results - TEH_U1

Oil & Gas Range 90 km	Y2000B	Y2020R	Y2020C	Y2020R vs Y2000B %Δ	Y2020C vs Y2020R %Δ	Y2020C vs Y2000B %Δ
Fuel Burn (kg)	353.4	316.7	280.8	-10.4	-11.3	-20.5
CO_2 (kg)	1116.7	1000.9	887.3	-10.4	-11.3	-20.5
NO_X (kg)	2.5	2.1	1.4	-16.0	-33.3	-44.0

Oil & Gas Range 180 km	Y2000B	Y2020R	Y2020C	Y2020R vs Y2000B %Δ	Y2020C vs Y2020R %Δ	Y2020C vs Y2000B %Δ
Fuel Burn (kg)	556.0	497.5	440.2	-10.5	-11.5	-20.8
CO_2 (kg)	1756.8	1572.0	1390.9	-10.5	-11.5	-20.8
NO_X (kg)	4.1	3.4	2.4	-15.9	-30.9	-42.0

Oil & Gas Range 332 km	Y2000B	Y2020R	Y2020C	Y2020R vs Y2000B %Δ	Y2020C vs Y2020R %Δ	Y2020C vs Y2000B %Δ
Fuel Burn (kg)	1018.8	911.7	807.7	-10.5	-11.4	-20.7
CO_2 (kg)	3219.4	2880.9	2552.3	-10.5	-11.4	-20.7
NO_X (kg)	7.7	6.5	3.6	-16.0	-44.6	-53.4

Environmental Assessment Example I

ATS Level Results - TEH_U1

Oil & Gas ATS	Y2000B	Y2020R	Y2020C	Y2020R vs Y2000B %Δ	Y2020C vs Y2020R %Δ	Y2020C vs Y2000B %Δ
Fuel Burn (kg)	663.6	593.6	525.5	-10.5	-11.5	-20.8
CO_2 (kg)	2096.8	1875.7	1660.6	-10.5	-11.5	-20.8
NO_X (kg)	5.0	4.2	2.4	-16.0	-42.9	-52.0

- Consistent reduction in fuel burn and CO_2 across the range of missions flown, ~ 10% between Y2020R and Y2000B and ~10% between Y2020C and Y2020R
- NOx reduction largely depends on mission profile and engine power setting, varies between 30% and 45% when comparing Y2020C against Y2020R

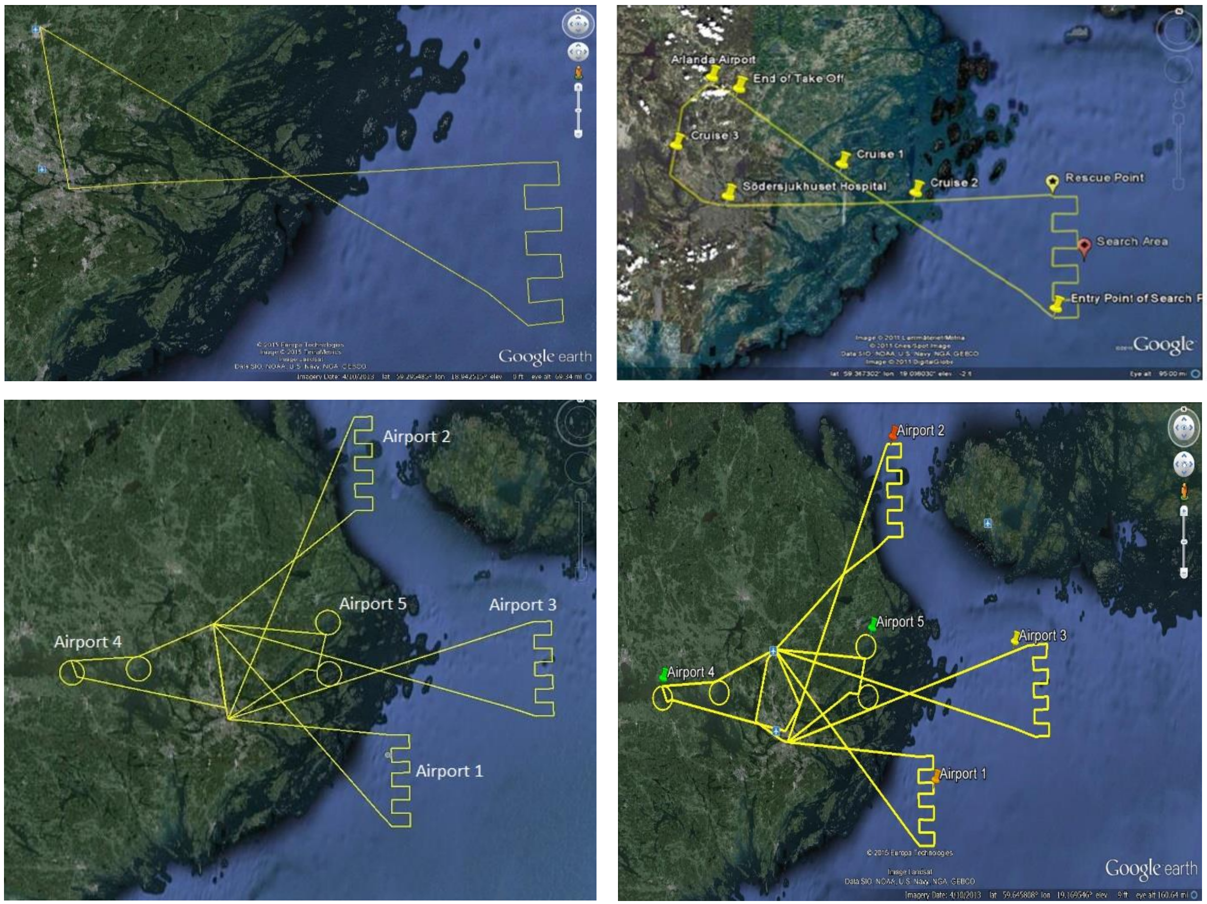
Environmental Assessment Example II
Scenario Definition for TEM

Search & Rescue Missions TEM

Fuel Economy | Population Avoidance

Mission Level

Airport Level

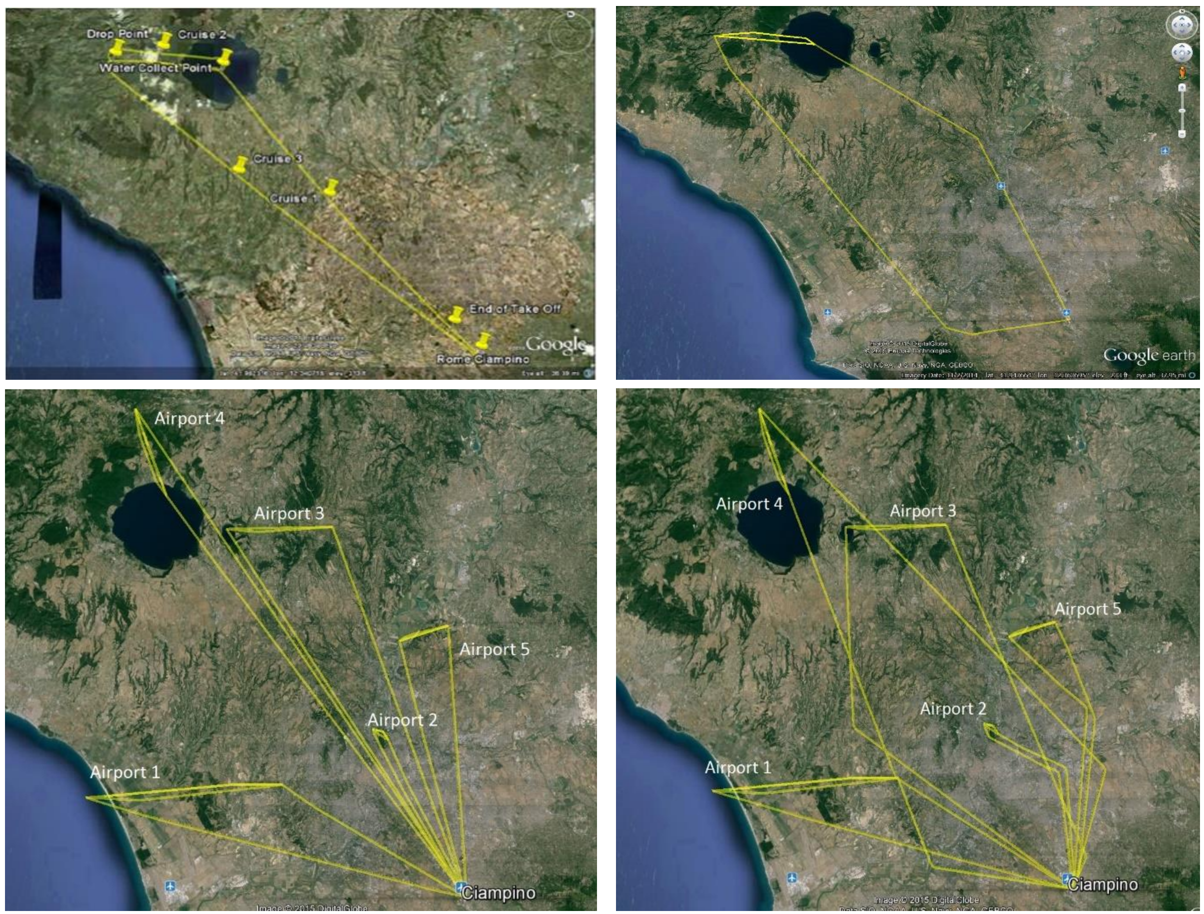


Environmental Assessment Example II
Scenario Definition for TEM

Fire Suppression Missions TEM

Fuel Economy | Population Avoidance

Mission Level | Airport Level



Environmental Assessment Example II
Operational Procedure for TEM

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- Typical procedure for a TEM helicopter on a Fire Suppression mission:
  1. The helicopter starts both engines and rotors on the ground at the helipad
  2. The helicopter remains in idle for 5 minutes
  3. The helicopter taxis to the main runway and awaits take-off clearance
  4. The helicopter lifts into hover
  5. The helicopter climbs to 3000 ft AGL at 80 knots
  6. The helicopter heads towards the designated water collection point at 120knots
  7. The helicopter, having reached the water collection point, descends to an altitude according to the specifications of the helicopter and the terrain altitude in order to effectively collect water
  8. The helicopter will hover at the water collection point for a small period of time until its tank or water bucket is filled
  9. The helicopter climbs to 1500 ft AGL at 80 knots
  10. The helicopter transits at 110 knots towards the location of the hypothetical fire incident
  11. The helicopter descends to the suitable operational altitude towards the incident location and initiates the fire extinguishing process
  12. The aforementioned process is repeated depending on the fire incident extent or other restrictions that will deem necessary the presence of the helicopter (e.g. monitoring of the fire and coordination of the firefighters)
  13. The helicopter climbs to 3000 ft AGL at 80 knots and heads towards the landing helipad at 120 knots
  14. The helicopter makes a landing hover at the helipad
  15. The helicopter sits for 1 minute with rotors turning on the ground
  16. The helicopter taxis according to the directions provided by the ATC of the airport

Load Type	Quantity	Weight (Kg)
Survival suits	12	36
Water tank + spraying system	1	136
Water to extinguish fires	650 liters	650
Total Payload	822 Kg	

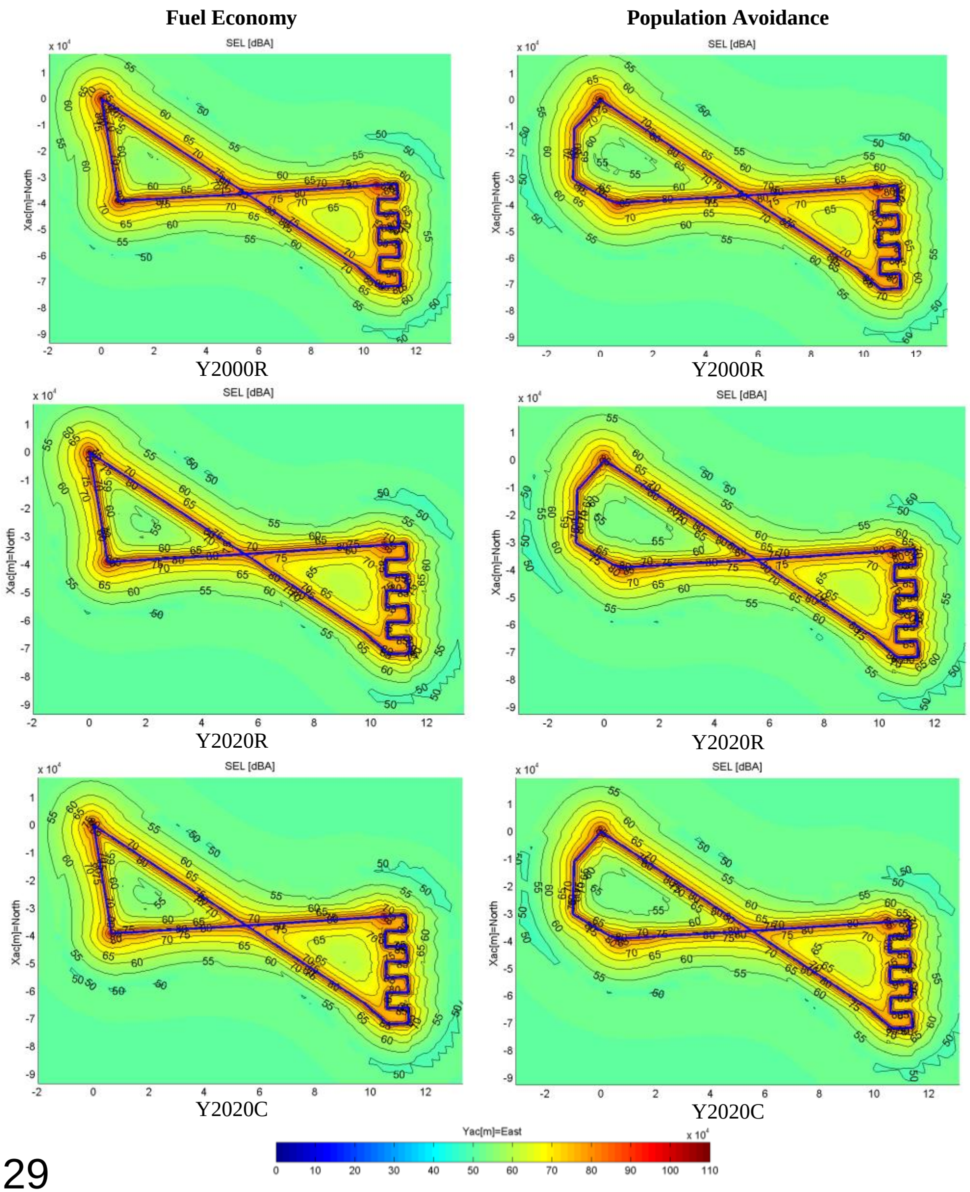
Environmental Assessment Example II

Mission Level Results - TEM

SAR Fuel Economy	Y2000B	Y2020R	Y2020C	Y2020R vs Y2000B %Δ	Y2020C vs Y2020R %Δ	Y2020C vs Y2000B %Δ
Fuel Burn (kg)	643.6	635.4	577.5	-1.3	-9.1	-10.3
CO_2 (kg)	2013.3	1987.5	1806.6	-1.3	-9.1	-10.3
NO_X (kg)	3.764	3.800	2.420	0.9	-36.3	-35.7

SAR Population Avoidance	Y2000B	Y2020R	Y2020C	Y2020R vs Y2000B %Δ	Y2020C vs Y2020R %Δ	Y2020C vs Y2000B %Δ
Fuel Burn (kg)	660.8	652.0	592.5	-1.3	-9.1	-10.3
CO_2 (kg)	2067.1	2039.4	1853.4	-1.3	-9.1	-10.3
NO_X (kg)	3.878	3.913	2.461	0.9	-37.1	-36.5

Environmental Assessment Example II
Mission Level Results - TEM

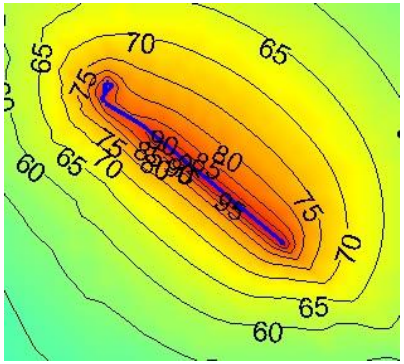


SAR Fuel Economy SEL dB(A)	Y2020R vs Y2000B %Δ	Y2020C vs Y2020R %Δ	Y2020C vs Y2000B %Δ
75-80 dB	-11.54	-1.46	-12.83
80-85 dB	-46.49	-3.03	-48.11
85-90 dB	-46.97	0.00	-46.97

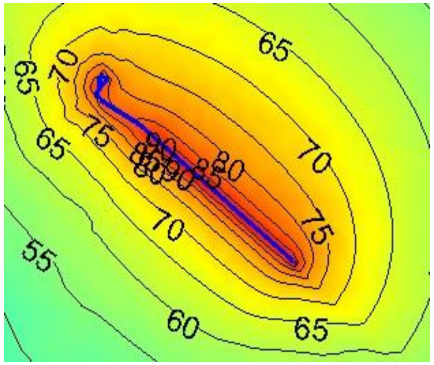
SAR Fuel Economy SEL dB(A)	Y2020R vs Y2000B %Δ	Y2020C vs Y2020R %Δ	Y2020C vs Y2000B %Δ
>75 dB	-20.78	-1.70	-22.12
>80 dB	-46.53	-2.78	-48.01
>85 dB	-46.97	0.00	-46.97
Average	-22.05	-0.91	-22.67

- … and similarly for Population Avoidance

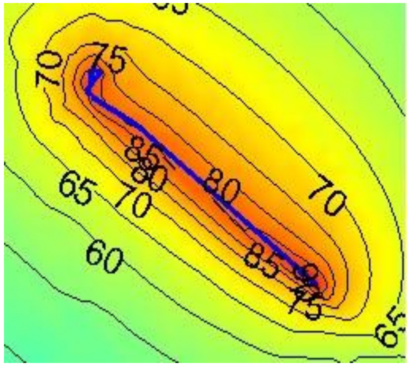
Environmental Assessment Example II
Mission Level Results - TEM



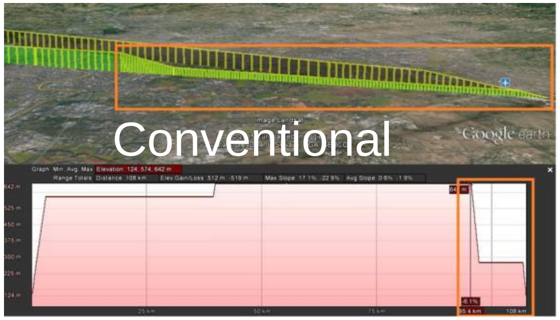
Y2000B conventional approach



Y2020R conventional approach



Y2020C GRC5 optimised approach



Benefits of GRC5 landing approach	Conventional landing		GRC5 optimized landing	Y2020R vs Y2000B %Δ	Y2020C vs Y2020R %Δ	Y2020C vs Y2000B %Δ
	Y2000B SEL area (km²)	Y2020R SEL area (km²)	Y2020C SEL area (km²)			
>75 dB	92.8	84.8	70.0	-8.6	-17.4	-24.5
>80 dB	48.8	44.0	36.3	-9.7	-17.6	-25.6
>85 dB	21.5	16.5	5.3	-23.3	-68.2	-75.6
			Average %Δ	-13.9	-34.4	-41.9

Environmental Assessment Example II

Airport Level Results - TEM

SAR Fuel Economy		Y2000B	Y2020R	Y2020C	Y2020R vs Y2000B %Δ	Y2020C vs Y2020R %Δ	Y2020C vs Y2000B %Δ
SAR #1	Fuel Burn (kg)	528.1	521.5	474.0	-1.3	-9.1	-10.2
	CO_2 (kg)	1651.9	1631.1	1482.6	-1.3	-9.1	-10.2
	NO_X (kg)	3.083	3.127	1.825	1.4	-41.6	-40.8
SAR #2	Fuel Burn (kg)	566.8	560.9	509.4	-1.0	-9.2	-10.1
	CO_2 (kg)	1772.9	1754.6	1593.4	-1.0	-9.2	-10.1
	NO_X (kg)	3.353	3.408	1.960	1.6	-42.5	-41.6
SAR #3	Fuel Burn (kg)	646.9	640.0	580.6	-1.1	-9.3	-10.2
	CO_2 (kg)	2023.4	2001.8	1816.1	-1.1	-9.3	-10.2
	NO_X (kg)	3.855	3.923	2.165	1.8	-44.8	-43.8
SAR #4	Fuel Burn (kg)	410.4	405.8	369.5	-1.1	-9.0	-10.0
	CO_2 (kg)	1283.8	1269.4	1155.8	-1.1	-9.0	-10.0
	NO_X (kg)	2.353	2.383	1.542	1.3	-35.3	-34.4
SAR #5	Fuel Burn (kg)	375.5	370.3	337.8	-1.4	-8.8	-10.1
	CO_2 (kg)	1174.6	1158.4	1056.5	-1.4	-8.8	-10.1
	NO_X (kg)	2.148	2.166	1.369	0.9	-36.8	-36.3

- … and similarly for Population Avoidance

Environmental Assessment Example II

ATS Level Results - TEM

SAR Fuel Economy	Y2000B	Y2020R	Y2020C	Y2020R vs Y2000B %Δ	Y2020C vs Y2020R %Δ	Y2020C vs Y2000B %Δ
Fuel Burn (kg)	506.0	501.1	455.3	-1.0	-9.1	-10.0
CO_2 (kg)	1582.7	1567.4	1424.1	-1.0	-9.1	-10.0
NO_X (kg)	2.948	2.998	1.860	1.7	-38.0	-36.9

SAR Population Avoidance	Y2000B	Y2020R	Y2020C	Y2020R vs Y2000B %Δ	Y2020C vs Y2020R %Δ	Y2020C vs Y2000B %Δ
Fuel Burn (kg)	511.2	506.8	460.0	-0.9	-9.2	-10.0
CO_2 (kg)	1599.1	1585.4	1439.0	-0.9	-9.2	-10.0
NO_X (kg)	2.988	3.044	1.856	1.9	-39.0	-37.9

- Large reduction in acoustic area footprint ~ 45% (for the higher dB levels) compared to today's technology
- ~10% reduction in fuel burn and CO_2
- ~45% reduction in NO_x (depends strongly on mission profile)

Environmental Assessment Example III
Scenario Definition for HCE

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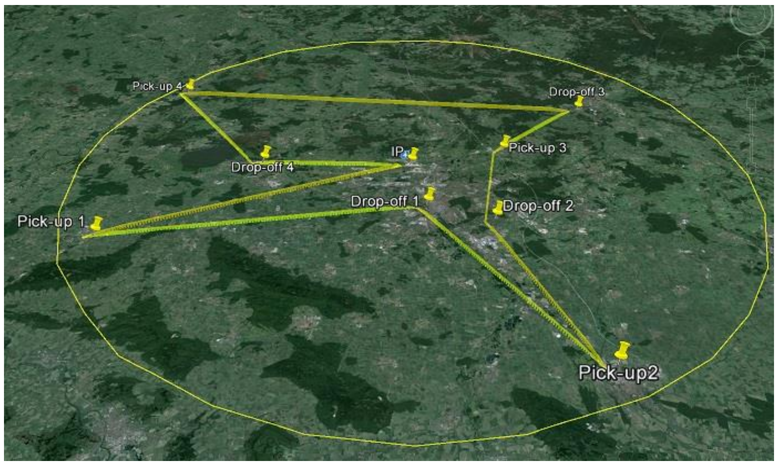
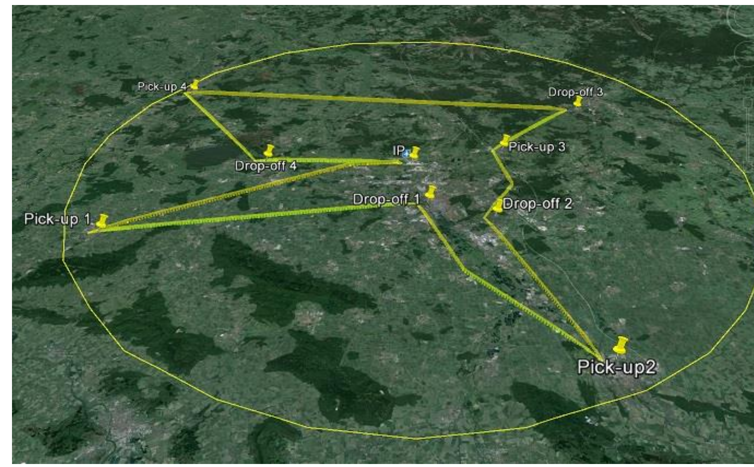
Passenger Missions HCE

Fuel Economy



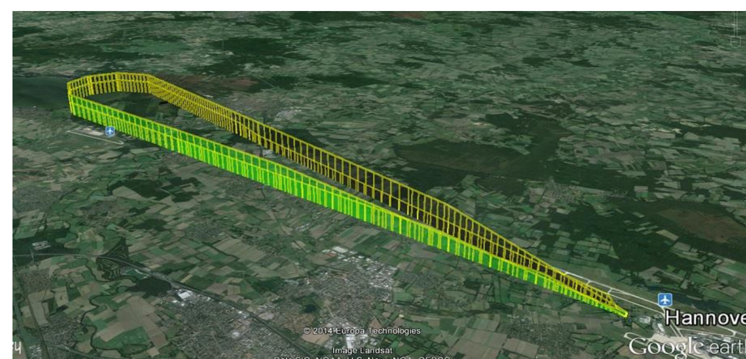
Population Avoidance



Training Missions HCE

Mission 1

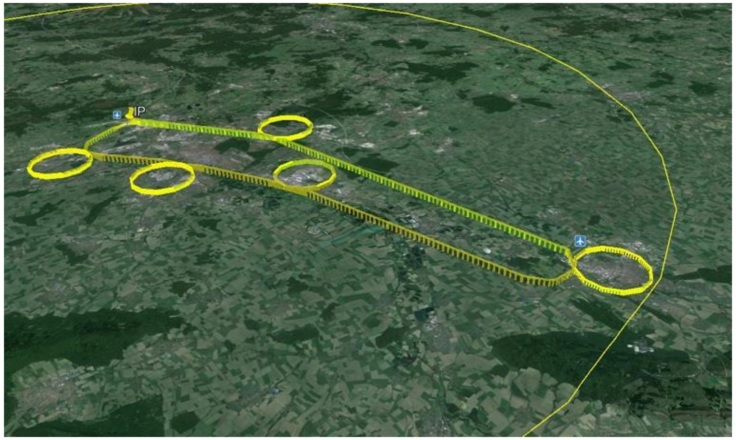
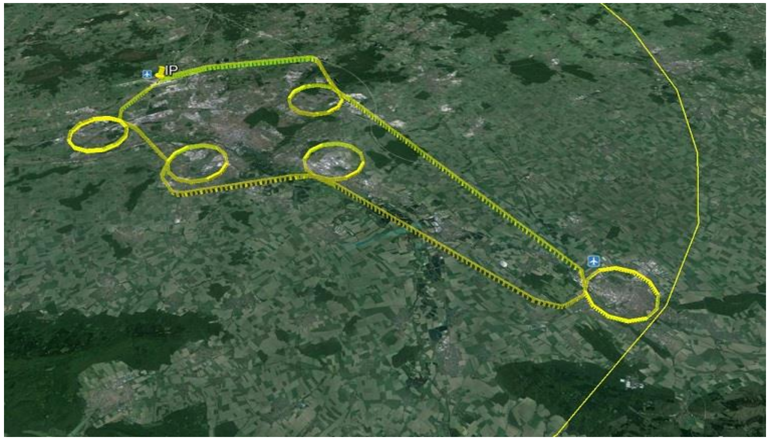
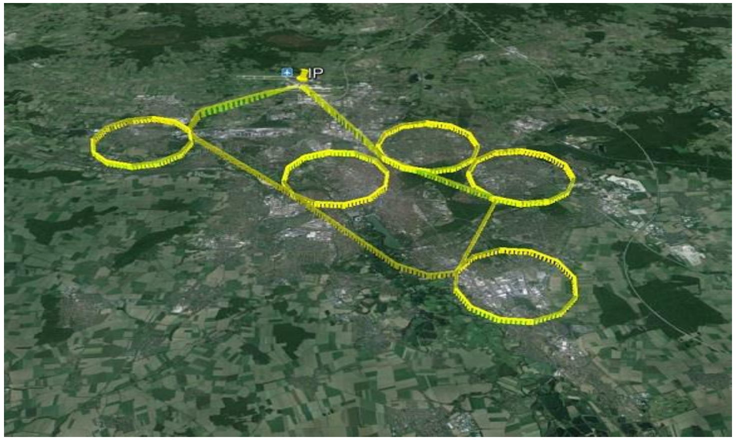
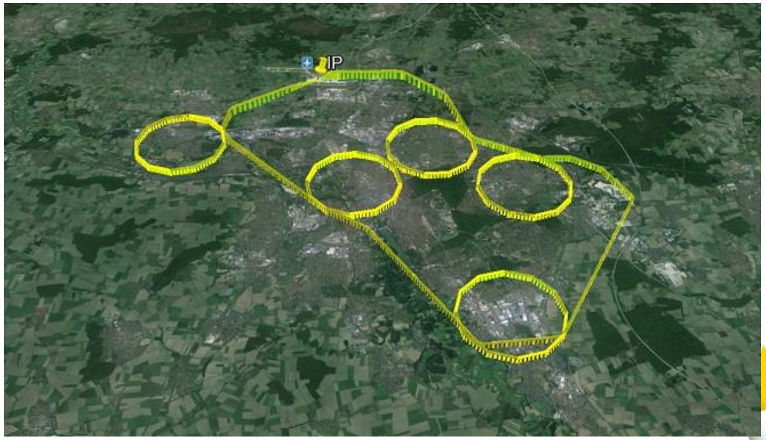
Mission 2



Environmental Assessment Example III

Scenario Definition for HCE

Police Missions HCE

	Fuel Economy		Population Avoidance
		Mission 1	
		Mission 2	

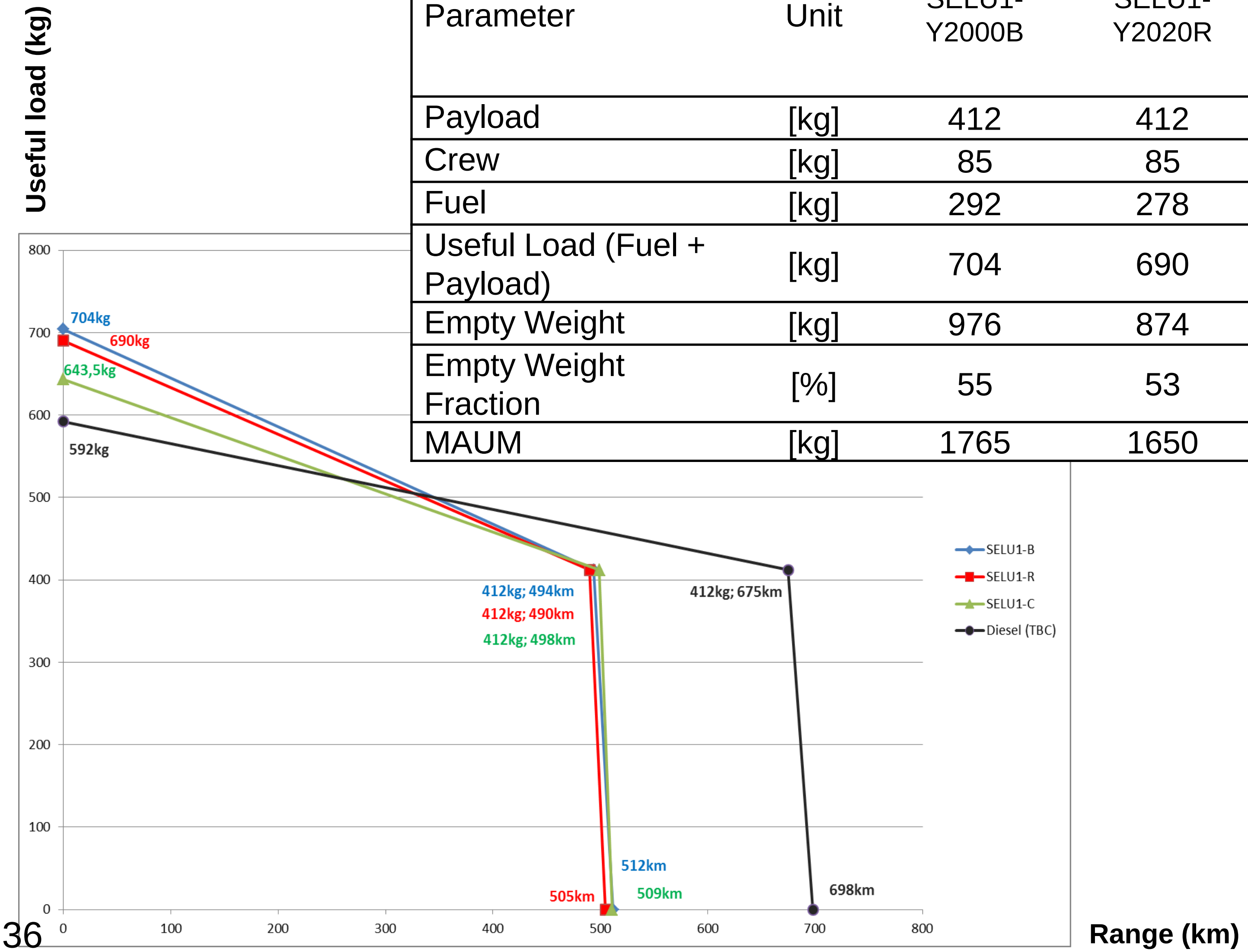
Environmental Assessment Example III
Operational Procedure for HCE

- Typical procedure for a HCE helicopter on a training mission:

1.The helicopter starts its engine and rotors on the ground at the helipad
2. The helicopter remains in idle for 5 minutes
3. The helicopter lifts into hover
4. The helicopter climbs to 1000 ft AGL at 80 knots
5. The helicopter transits at 100 knots in level flight
6. The helicopter performs a counter-clockwise turn with 1 mile radius at 60 knots
7. The helicopter climbs to 1500 ft with target speed 100 knots
8. The helicopter performs a counter-clockwise turn with 1 mile radius at 60 knots
9. The helicopter descends towards the originating runway and performs hover above the initial point at 200 ft AGL
10. The helicopter climbs to 2000 ft AGL at 80 knots
11. The helicopter transits at 100 knots in level flight
12. The helicopter performs a counter-clockwise turn with 1 mile radius at 60 knots
13. The helicopter climbs to 2500 ft with target speed 100 knots
14. The helicopter performs a counter-clockwise turn with 1 mile radius at 60 knots
15. The helicopter descends to 1000 ft AGL with target airspeed 100 knots
16. From a distance of 1 mile the helicopter begins its landing procedure towards the helipad
17. The helicopter lands at the original helipad
18. The helicopter sits for 1 minute with rotors turning on the ground

Environmental Assessment Example III
Payload/Range Calculations for HCE

Parameter	Unit	SELU1-Y2000B	SELU1-Y2020R	SELU1-Y2020C	HCE Y2020+
Payload	[kg]	412	412	412	412
Crew	[kg]	85	85	85	85
Fuel	[kg]	292	278	232	180
Useful Load (Fuel + Payload)	[kg]	704	690	644	592
Empty Weight	[kg]	976	874	859	911
Empty Weight Fraction	[%]	55	53	54	57
MAUM	[kg]	1765	1650	1588	1588



Environmental Assessment Example III
Mission Level Results - HCE vs SEL_U1

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Comparison #1

Passenger Fuel Economy	HCE Y2020C vs SEL_U1 Y2020R %Δ	HCE Y2020C vs SEL_U1 Y2020C %Δ
CO_2 (kg)	-58.45	-49.93
NO_X (kg)	-64.30	-11.46

- Direct comparison, assessed on exactly the same mission profile

Comparison #2

Passenger Fuel Economy	HCE Y2020C vs SEL_U1 Y2020R %Δ	HCE Y2020C vs SEL_U1 Y2020C %Δ
CO_2 per km	-67.73	-62.08
NO_X per km	-68.02	-34.15

- Different mission profiles – results normalised wrt distance (44km mission range for SEL_U1 and 250km for HCE)

Comparison #3

Passenger Fuel Economy	HCE Y2020C vs SEL_U1 Y2020R %Δ	HCE Y2020C vs SEL_U1 Y2020C %Δ
CO_2 per hr	-52.34	-44.00
NO_X per hr	-52.76	-2.77

- Different mission profiles – results normalised wrt time (0.48hr mission duration for SEL_U1
  and 1.85hr for HCE)

Environmental Assessment Comparison

Mission Level Results

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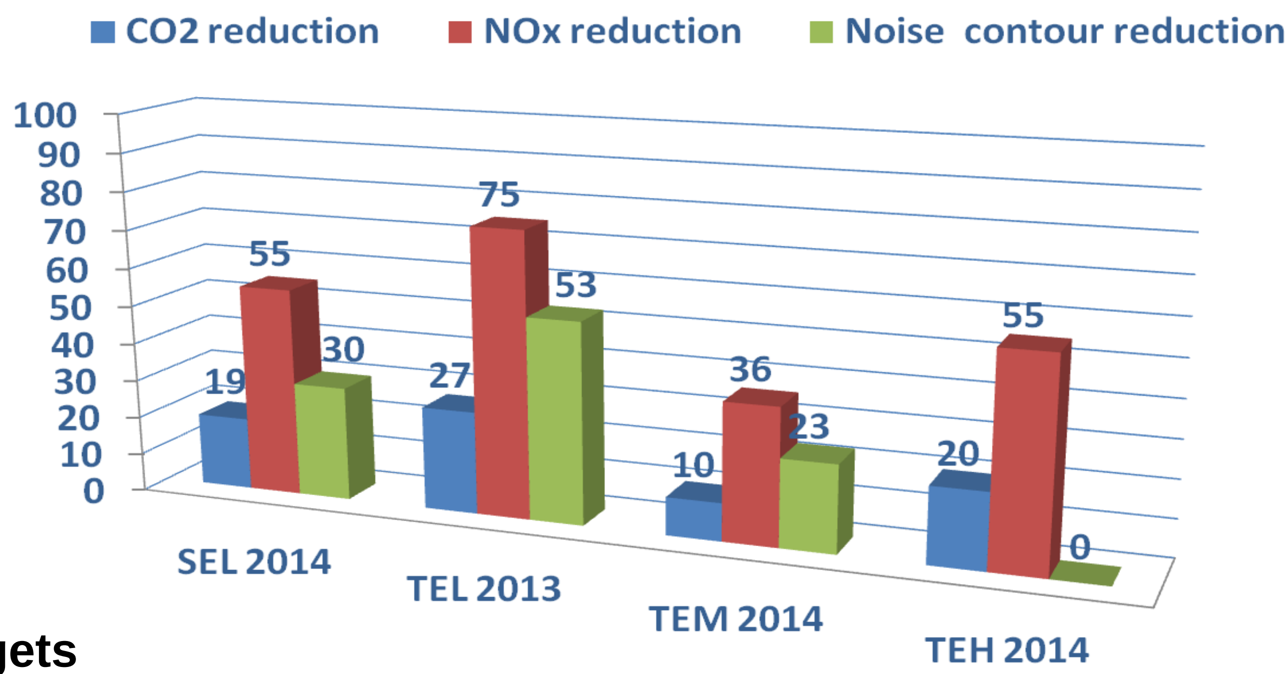
Y2020C vs Y2000B %Δ



Set Performance Targets

	CO2	NOx	Noise contour area reduction
SEL	-10 to -25%	-50 to -65%	-50%
TEL	-25 to -40%	-30 to -50%	-50%
TEM	-15 to -30%	-55 to -70%	-50%
TEH	-15 to -35%	-55 to -70%	N/A

Main Topics

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1 Main Objective

2 Introduction

3 Methodology

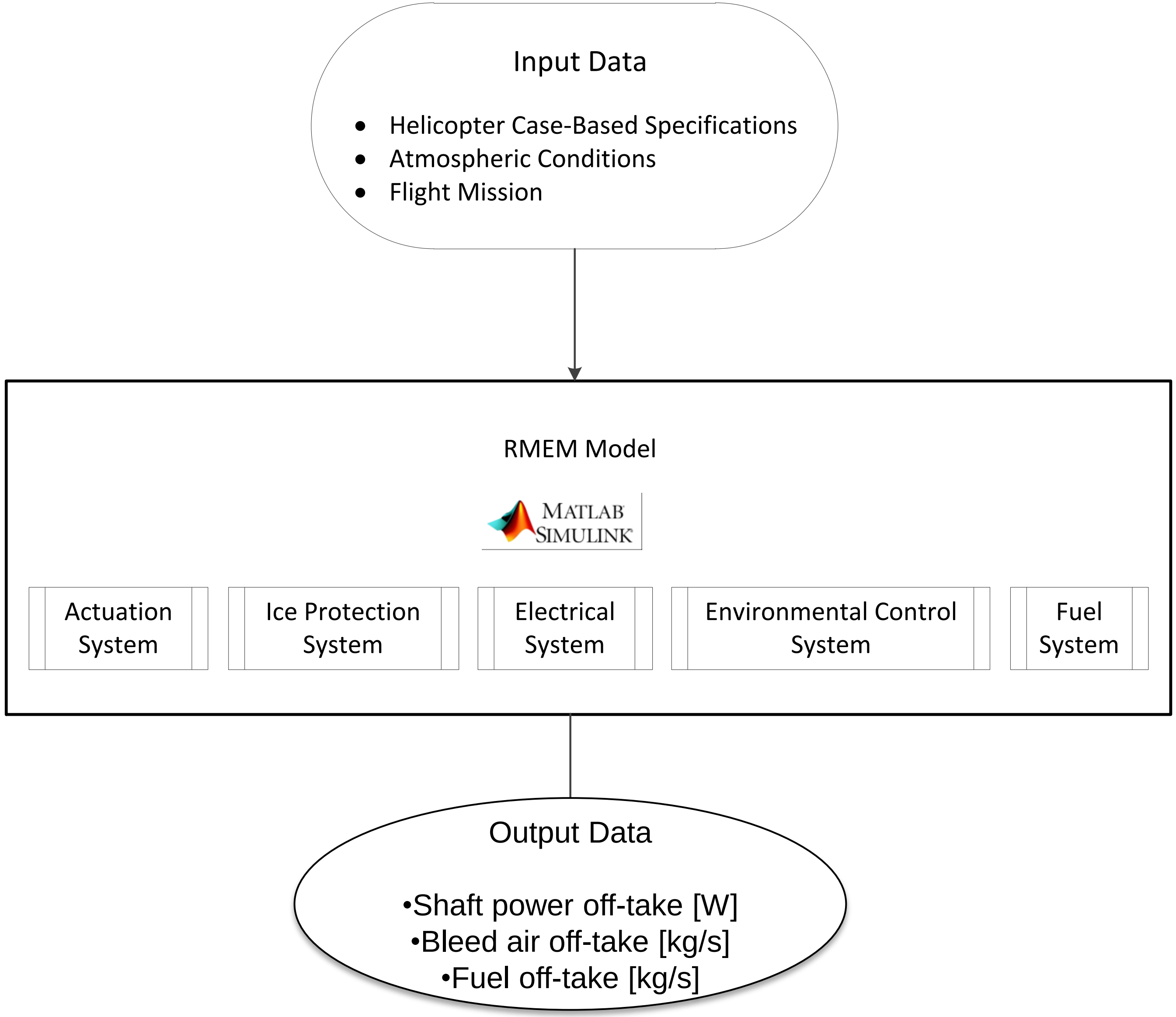
4 Environmental Assessment Examples

5 Other Collaborative Work

6 Conclusions

Other Collaborative Work

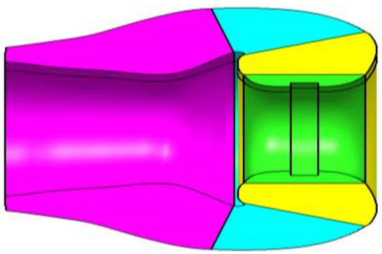
RMEM Platform Overview

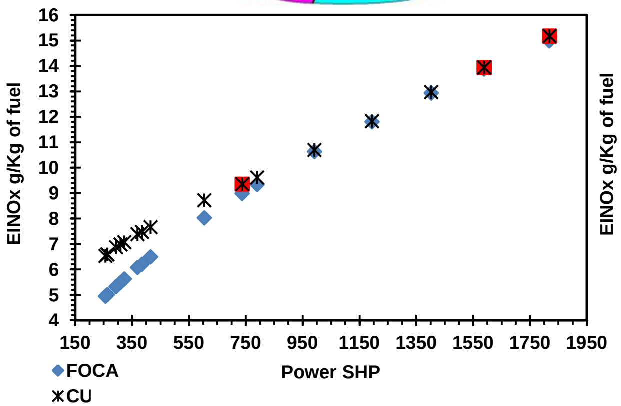


Other Collaborative Work
Turboshaft Engine Emissions Prediction

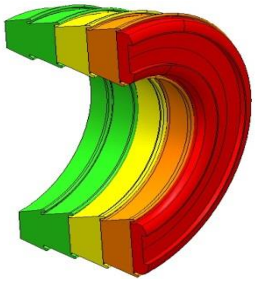
Current rotorcraft combustor models library – representing SEL,TEL & TEH rotorcraft configurations

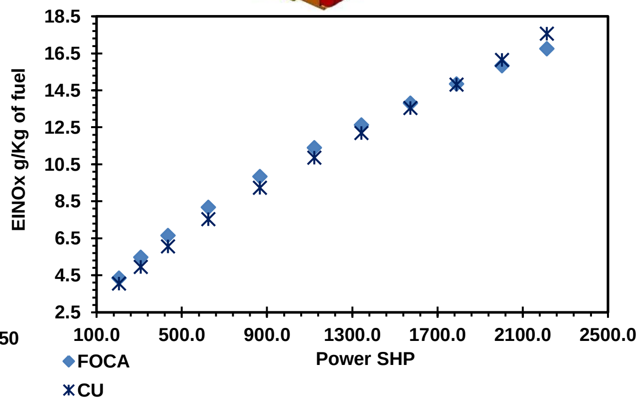
1. Reference Turbomeca Makila 1A1



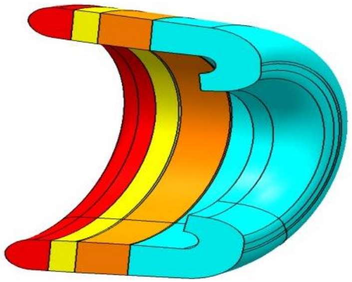


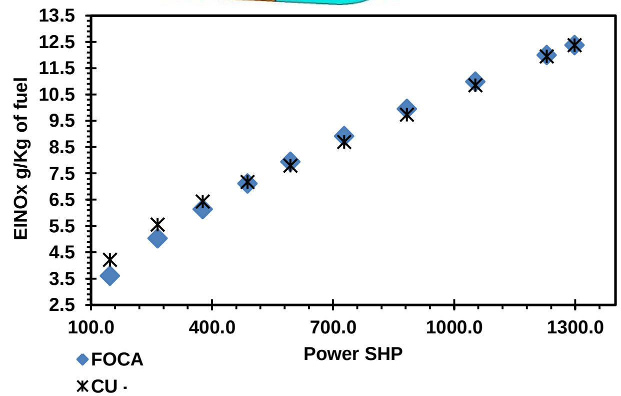
2. Reference General Electric T700_T6A



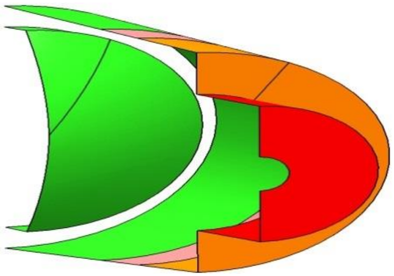


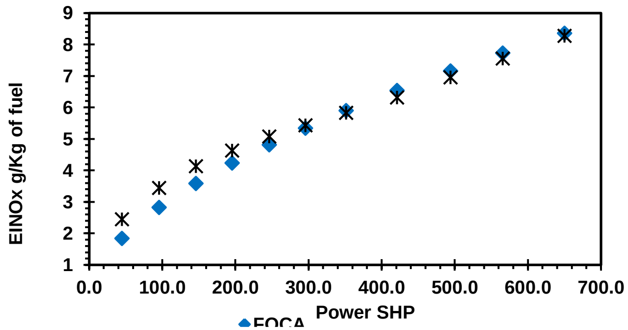
3. Reference Pratt & Whitney PT6A_5AG





4. Reference Rolls Royce Allison 250 C30S





**FOCA Data– Federal Office of Civil Aviation – Switzerland*
**CU – Cranfield University Emissions Model Hephaestus*

Main Topics

Conclusions

- Effective collaboration between TE and GRC ITD through GRC7
- Collaboration with the SAGE ITD on emissions predictions
- Implementation of a wide range of helicopter models
- All GRC helicopter models delivered/being assessed
- On-going assessments cover 100% of the existing RC fleet
- Continuous model update until the end of the program
- Increased accuracy through TRL improvement

References

- [1] Gervais, M., Gareton, V., Dummel, A., Heger, R."Validation of EC130 and EC135 Environmental Impact Assessment using HELENA", American Helicopter Society 66th Annual Forum, Phoenix, AZ, May 11-13, 2010.
- [2] FRIENDCOPTER http://www.friendcopter.org
- [3] NICETRIP http://nicetrip.onera.fr
- [4] NLR GSP http://www.gspteam.com/
- [5] Noesis Solutions N.V., OPTIMUS Rev. 9 SL1, May 2010
- [6] RESPECT http://www.sciencedirect.com/science/article/pii/S1290095801901145

Image courtesy of EAA.org

Thank you for your attention