Semiannual Meeting of the US/French MoA

Task V
Environmentally Friendly Rotorcraft Concepts

2011-2014

Principal Investigators

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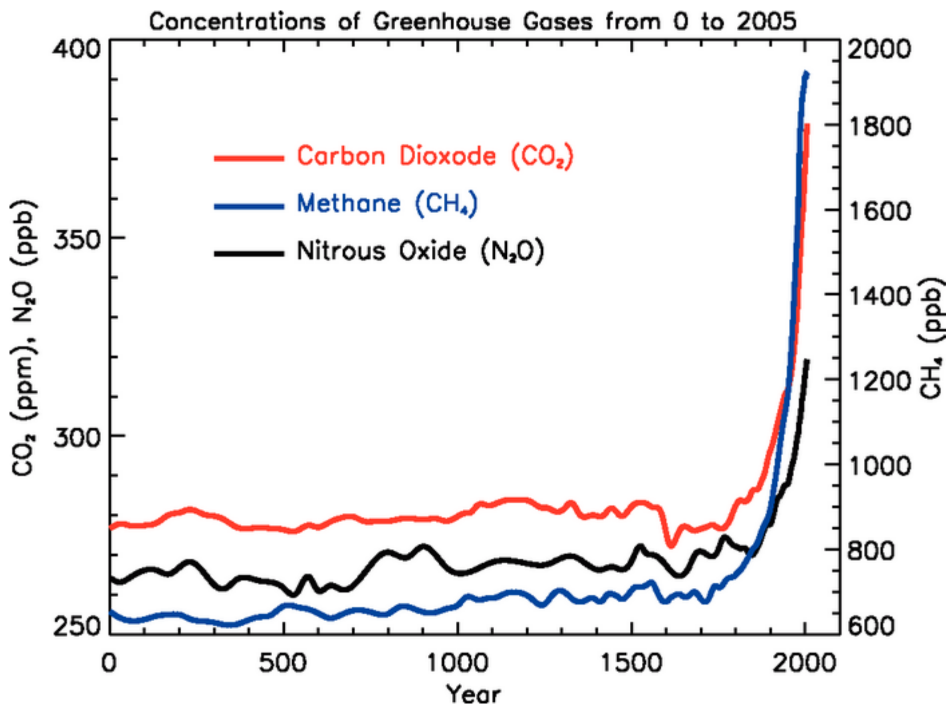
Management Overview

Motivation:

- Greenhouse gas concentrations have increased well beyond their pre-industrial levels due to human activities
- Aircraft emissions are becoming regulated in industrialized nations, so future rotorcraft will need to be designed for minimal environmental impact



Task V Environmentally Friendly Rotorcraft Concepts

Management Overview

Objectives:

- Determine suitable metrics to measure environmental impact of rotorcraft, focusing first on air pollution
- Integrate performance metrics with rotorcraft design codes
- Generate rotorcraft designs with minimal environmental impact

Outcomes:

- Obtain an understanding of how targeting reduced emissions affects the rotorcraft design process
- Advance the capability of existing rotorcraft design tools to include environmental performance metrics

Tools:

- Evaluation and predesign: NDARC and CREATION
- Flight simulation: CAMRAD II and HOST

Management Overview

1- Environmental Metrics Definition

1.1- Survey papers on available metrics
1.2- Proposals for env. impact metrics
- Revisit proposals in Year 1, Year 2, Year 3

2- Flight Perf. Metrics Definition

2.1- Definition of 3 baseline configs. (Heli, Tiltrotor, Compound)
2.2- Definition of performance metrics
2.3- Initial comparisons of ONERA/NASA calculations

3- Metric Computation for Existing Concepts

3.1- Environmental impact & flight performance analysis
3.2- Comparison of NASA/ONERA computations on the 3 baseline configs.

4- Designs With Environmental Constraints

4.1- Integration of environmental constraints into the evaluation and design tools
4.2- Use of NDARC/CREATION to generate alternate designs
4.3- Comparison of environmentally friendly designs w.r.t. the 3 baseline configs.
4.4- Joint paper

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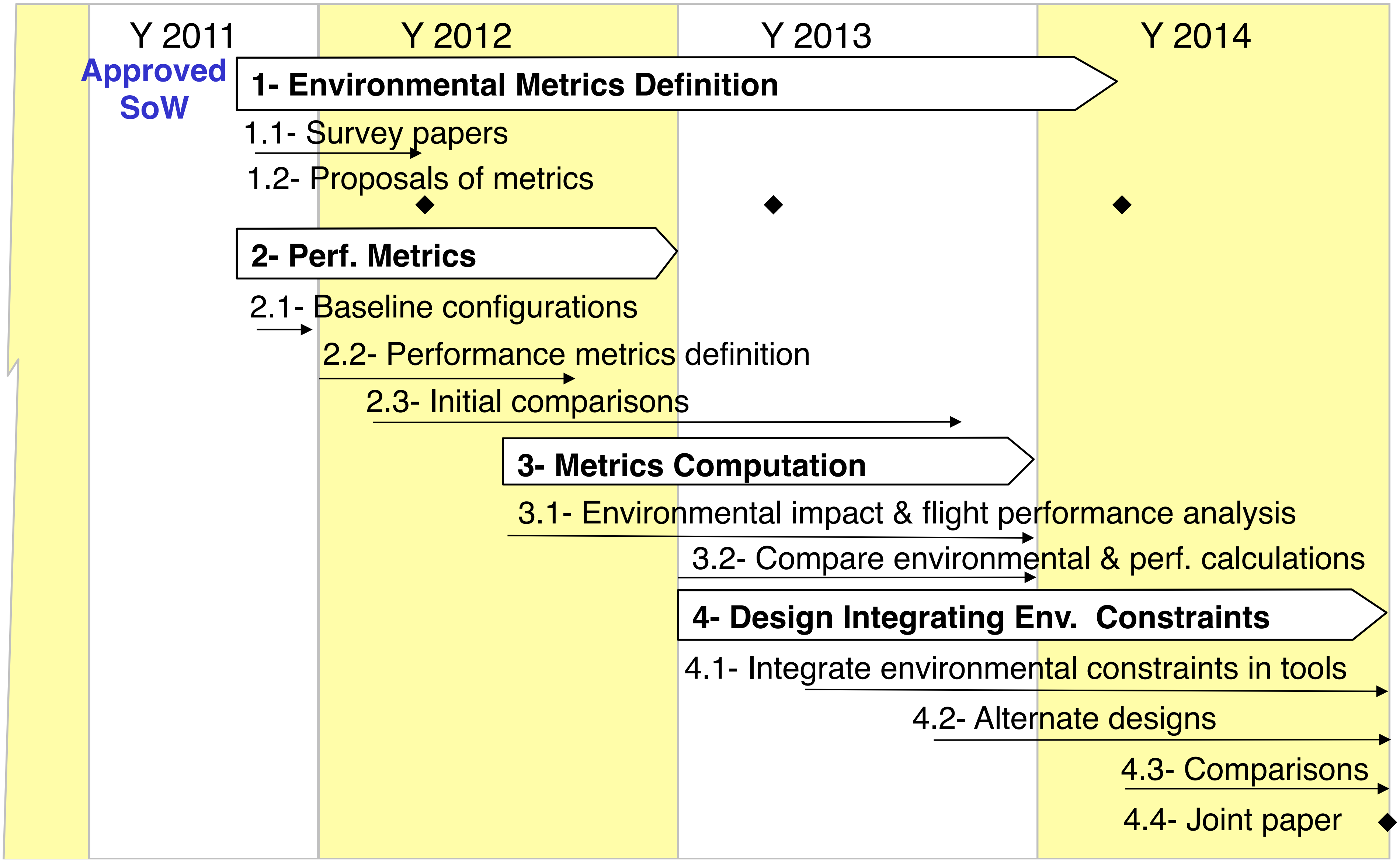
Management Overview



Task V Action Items

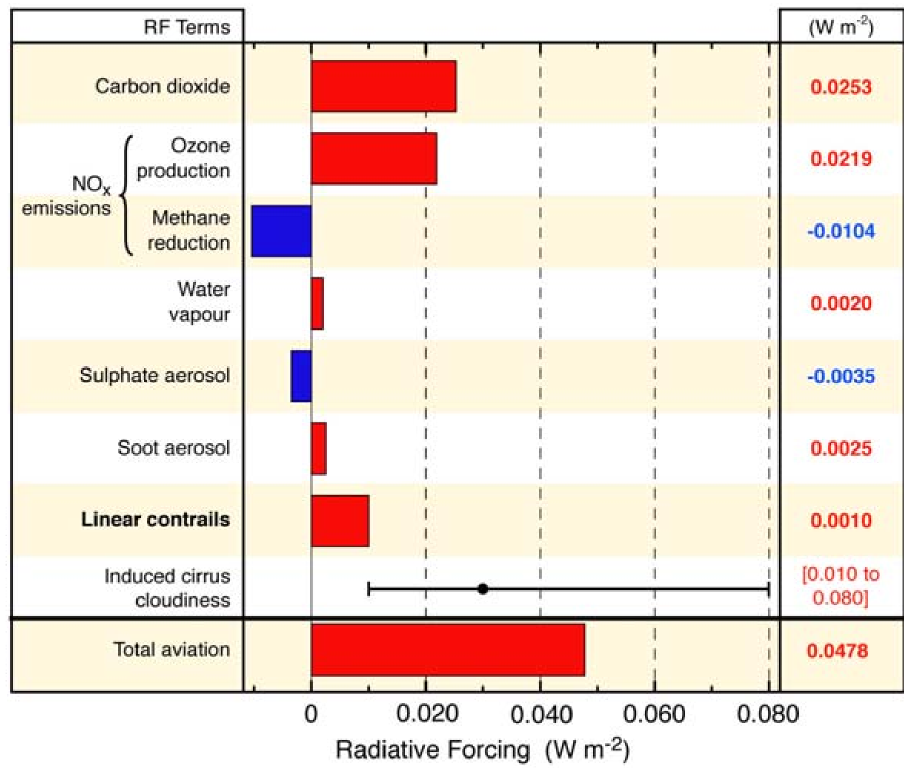
Personnel Exchange

There is still interest, but budget constraints on the NASA Rotary Wing Program make personnel exchange infeasible through at least Oct. 2014

Previous Completed Tasks 1.1 and 1.2 – Env. Metrics

Metric survey papers

- Identified historic trends in pollution sources and concentrations
- Examined the role of rotorcraft in generating air pollution
- Identified several candidate metrics for evaluating rotorcraft designs
- Metrics can be normalized by either time or distance and useful load (e.g.: metric per hour/mile per 100kg of useful load)
- Total air pollution should be assessed; not just CO_2
- Initial focus on CO_2 and NO_x emissions

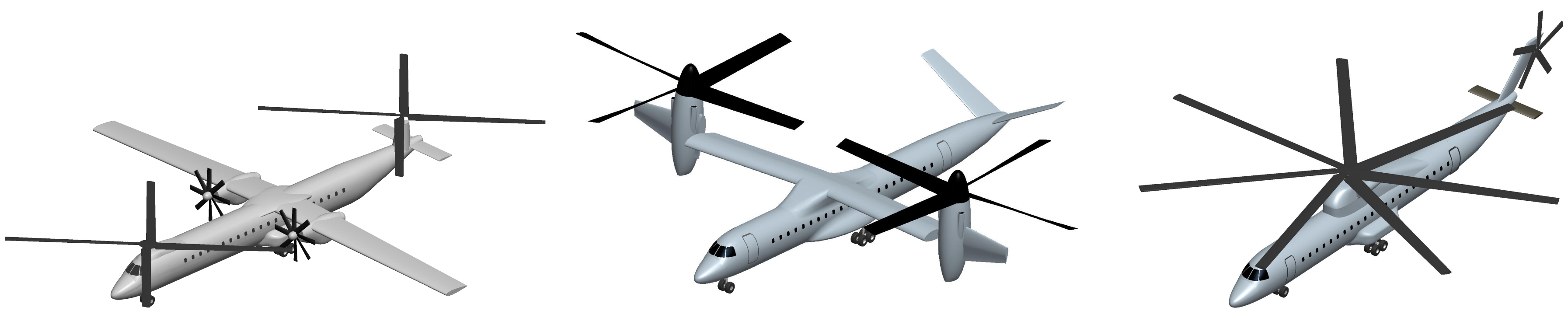


Aviation Radiative Forcing Components in 2005

Previous Completed Tasks
2.1 – Baseline Configs

Defined three baseline configurations

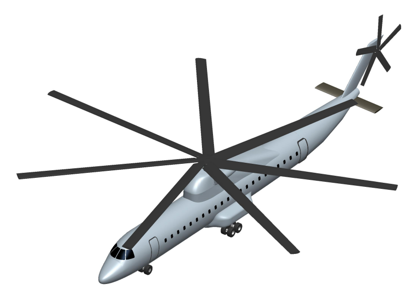
- 90 passenger capacity
- 500 nm range
- 75,000 – 100,000 lb design gross weight



Previous Completed Tasks

2.2 and 2.3 – Perf. Comparisons

- Performance Metrics
  - Power required, broken down to components
  - Figure of merit and cruise L/D_e
- Performance Comparisons
  - Rotor power computed with both momentum theory and free wake
  - Good agreement for the 90-passenger helicopter
  - Good agreement between NDARC and CREATION engine models



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Ongoing Tasks

Helicopter Sizing in CREATION

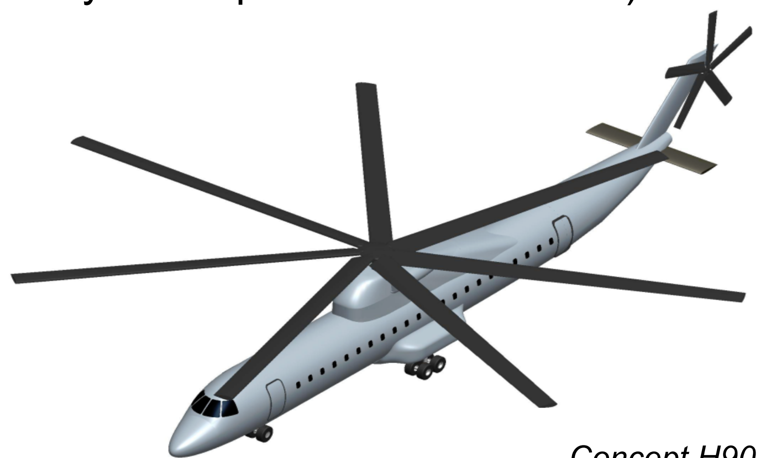
Case of study: Heavy transport helico 90 pax

(inspired from a NASA study which provides a reference)

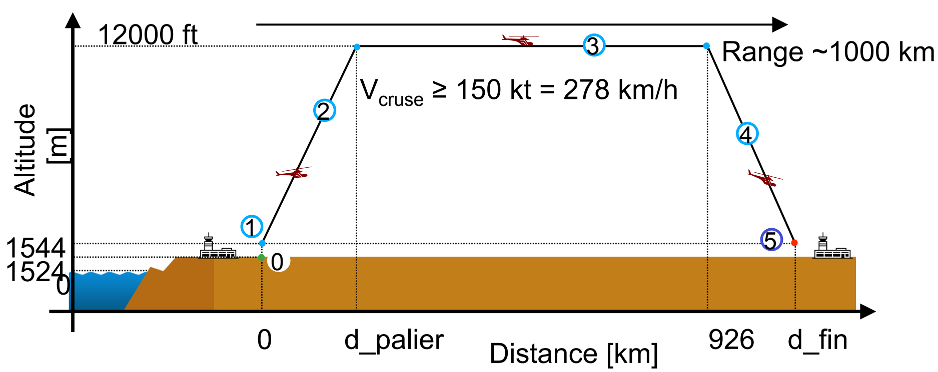
Mission and Specifications:

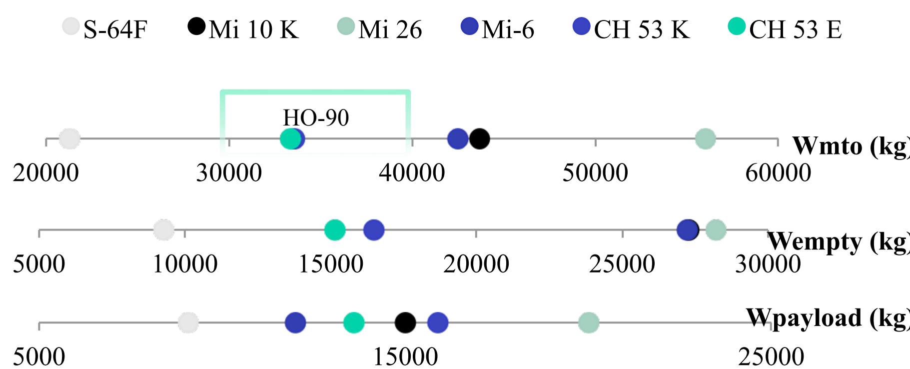
- 90 passagers
- Range ≥ 1000 km
- Cruse speed ≥ 280 km.h^{-1}
- Cruse altitude= 12 000 ft

- Mission profile:



Concept H90 - NASA





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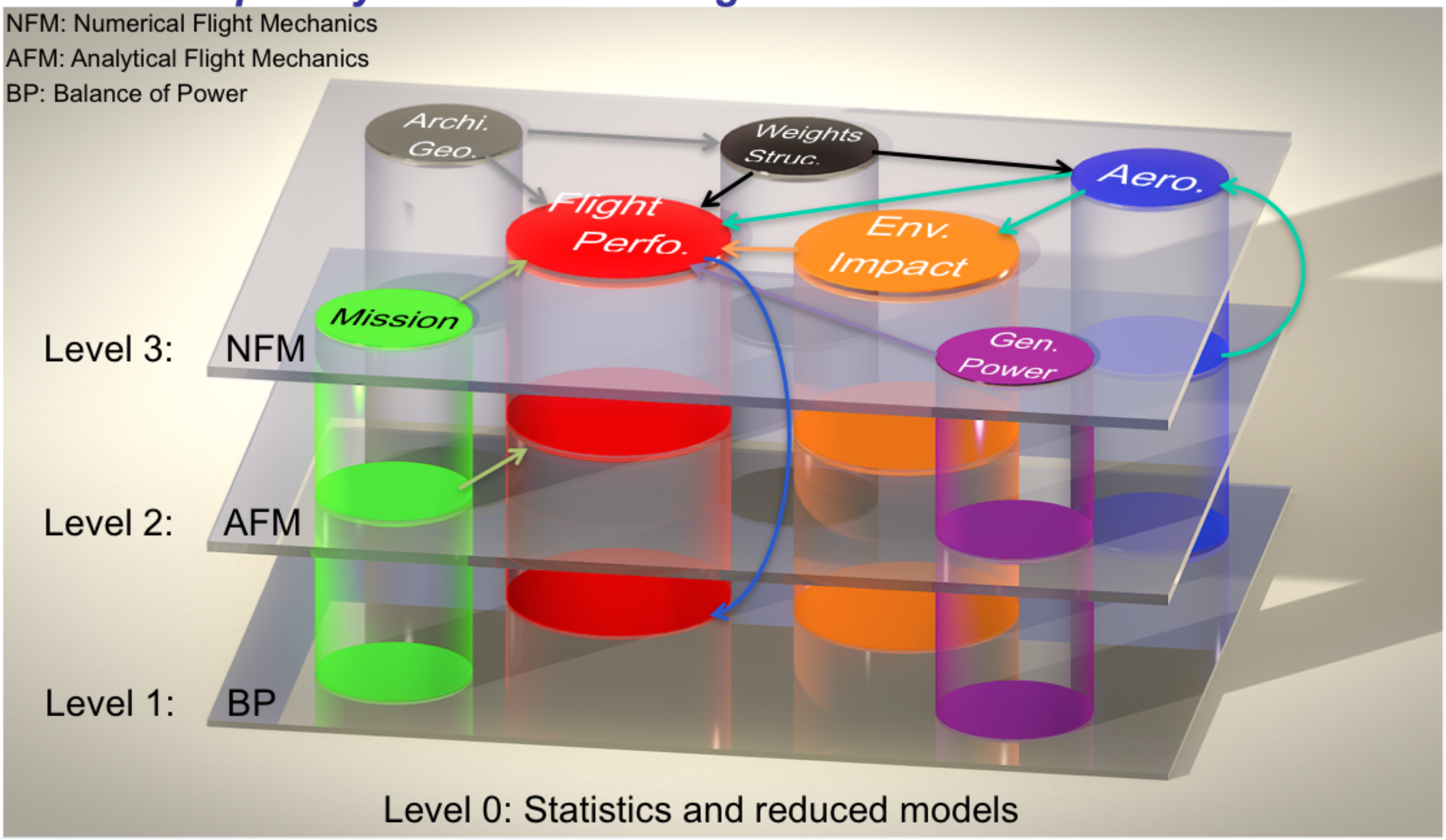
Ongoing Tasks

Helicopter Sizing in CREATION

Multidisciplinary & Multi-modeling levels calculation chain



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Ongoing Tasks

Helicopter Sizing in CREATION

Presizing loops in ModelCenter

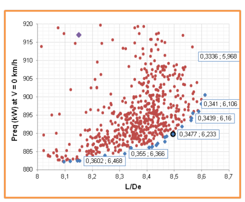
5 main steps:

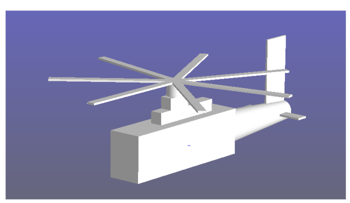
1 – Initialization with modeling level 0

2 – Optimization loop with level 1

- Test on constraints
- Evaluation models & engine presizing
- Loop on weight

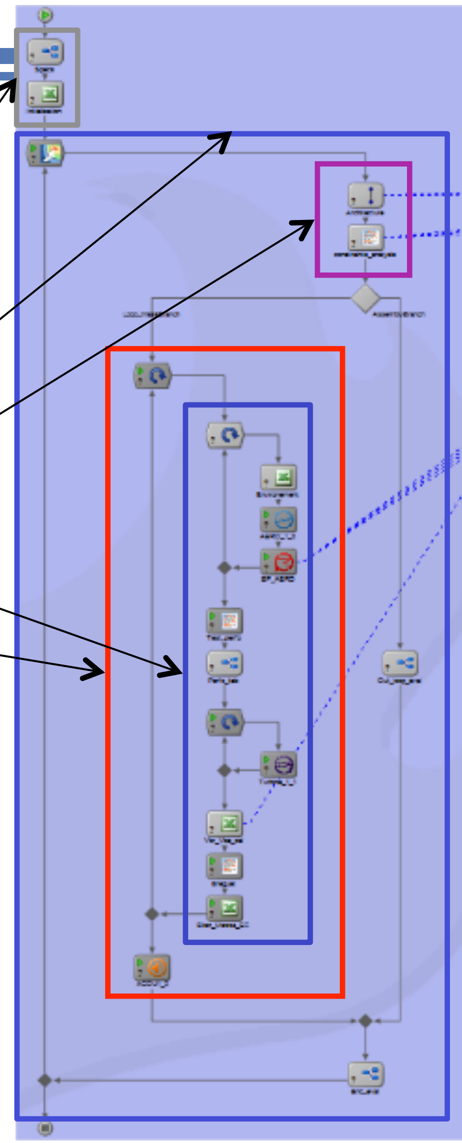
3 – Analysis of results + visualization





4 – More detailed presizing with levels 2 & 3

5 – Iteration between levels 1 & 3



Goals:
Min(Wfuel)
Max(Vcruse)
Min(Noise)
Min(Wempty)

Ongoing Tasks

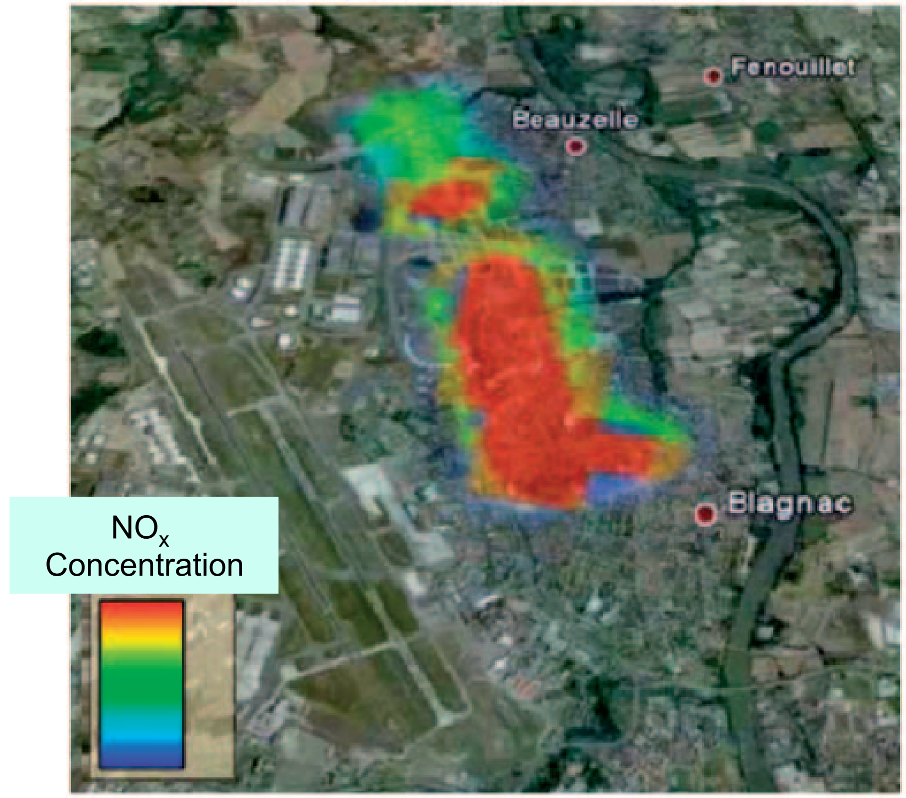
3.1 and 3.2 – Metric Computations

- Determine suitable metrics to measure environmental impacts
- Determine quantity of pollutants emitted
- Compute metrics for existing designs
- Determine how application of metrics drives rotorcraft designs

Ongoing Tasks

1.2 – Environmental Metrics Definition

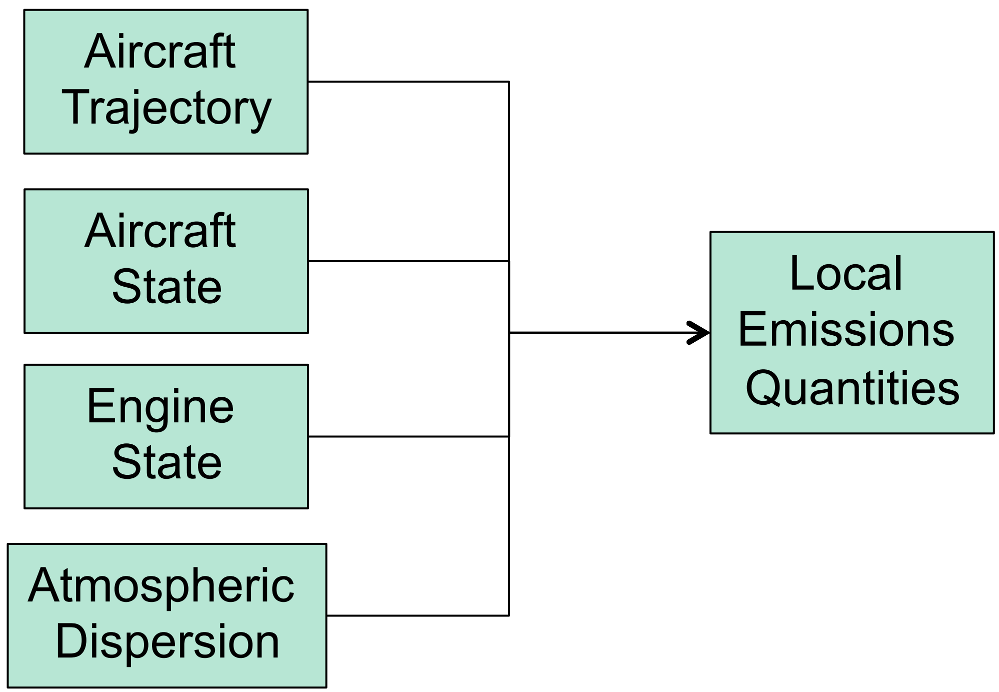
- Want to look at both local and global effects
- Local effects are in terms of air quality, which is a measure of pollutant quantities
- Global effects are in terms of climate change (warming)



Aubry, S., et al. “Evaluating the local environmental impact of air traffic with air transport systems evaluation infrastructure: outputs and validation walkthrough,” July 2011.

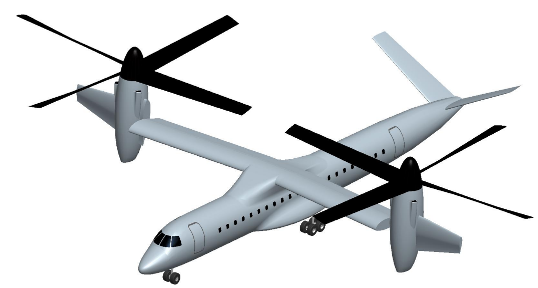
Evaluating Local Emissions

- IESTA – Air Transport System Evaluation Infrastructure



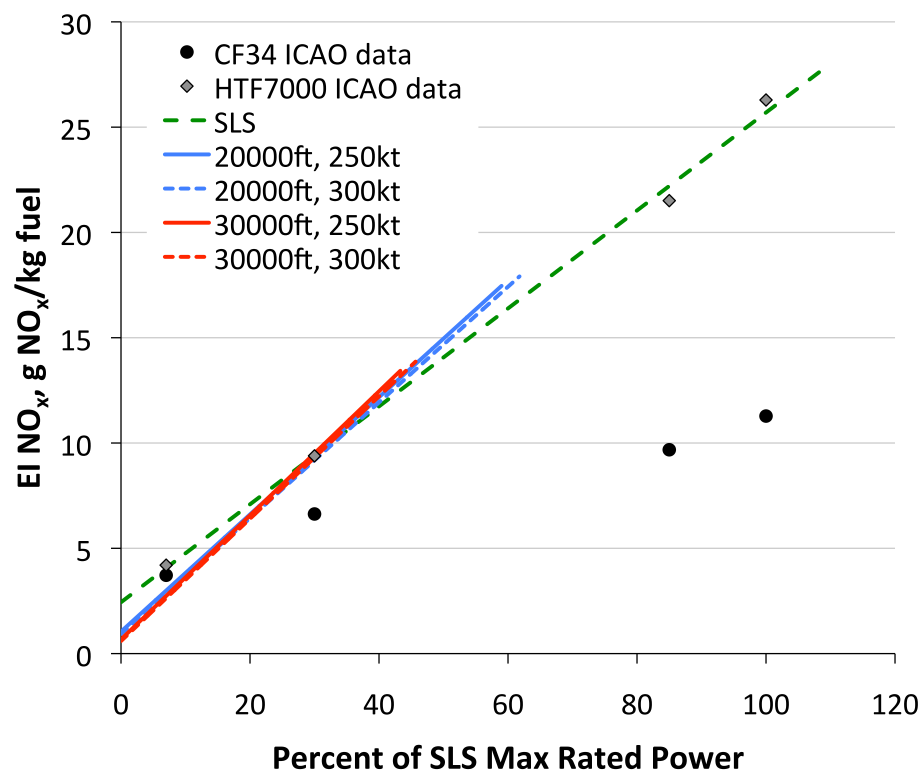
Quantifying Emissions

- Emissions index (EI): quantity emitted per quantity of fuel burned
- CO_2, water vapor, SO_4, and soot have constant EI
- $EINO_x$ depends on several variables
  - Engine technology
  - Inlet pressure and temperature conditions (altitude)
  - Throttle setting
- Very limited NO_x data for turboshaft engines



Quantifying NO_x Emissions

- Very little public emissions data for turboshaft engines
- Use NDARC engine output with turbofan NO_x data and DLR fuel flow corrections to estimate $EINO_x$



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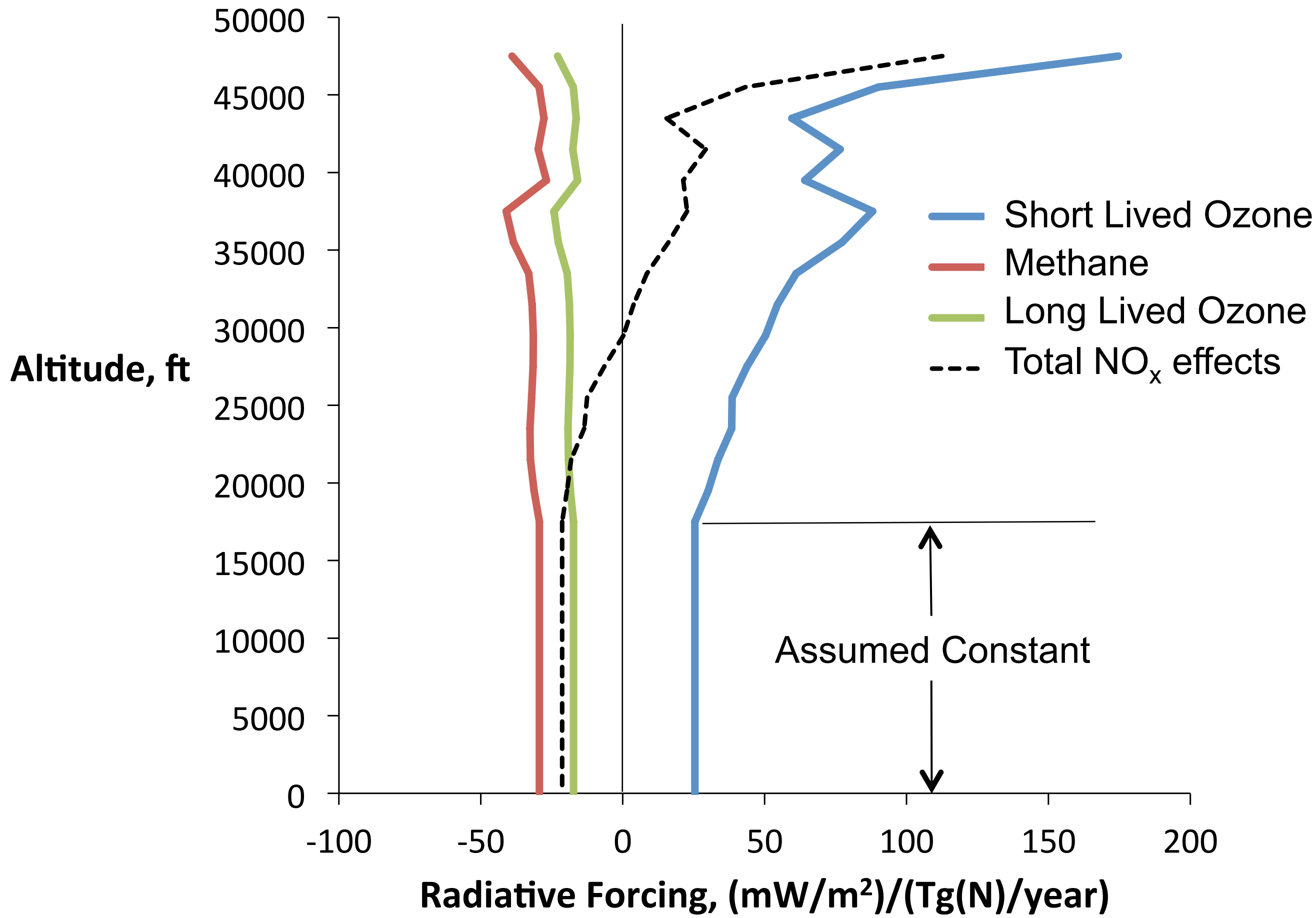
Quantifying NO_x Impacts



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Candidate Metric
ATR – Average Temp. Response

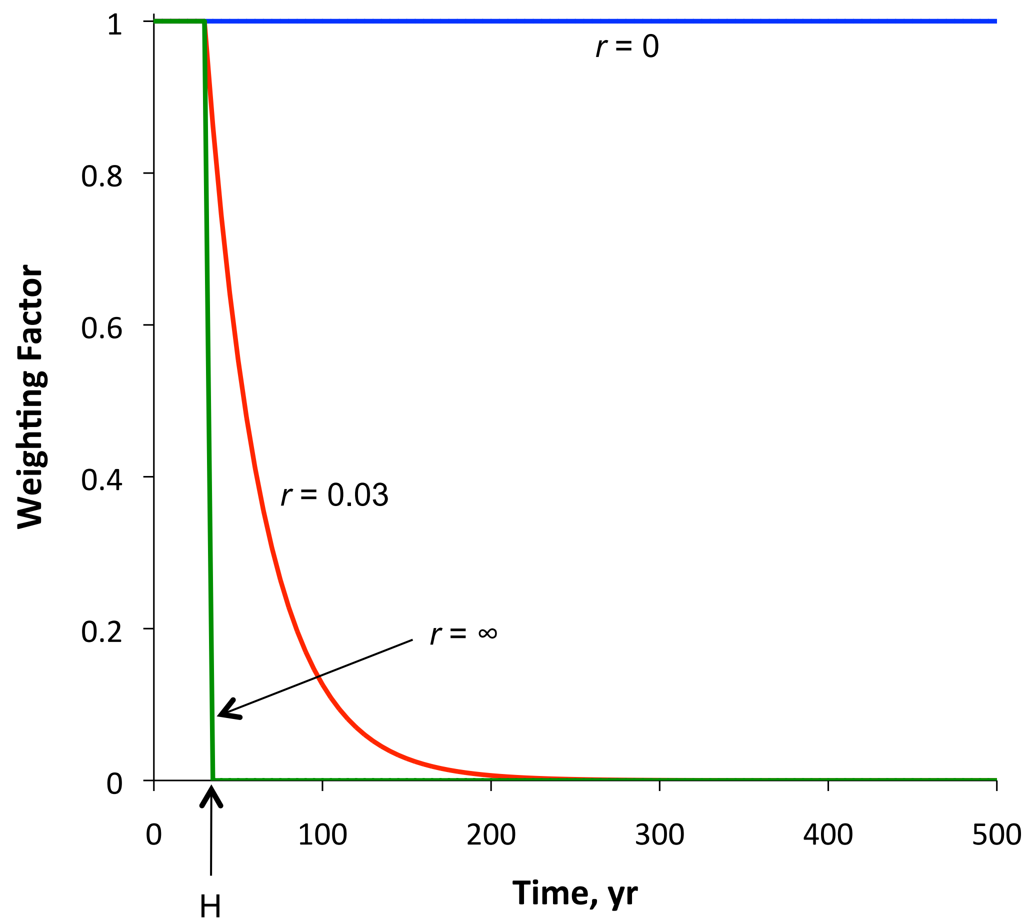
- Recently developed metric measuring global impact of aviation emissions
- Based on radiative forcing caused by various emission species
  - CO_2, NO_x, water vapor, SO_4, soot, and aviation induced cloudiness (AIC)
- Expresses climate impact as integrated temperature change resulting from operation of a particular aircraft design

$$ATR_H = \frac{1}{H}\int_0^{\infty} \Delta T_{sust,H}(t)w(t)\,dt$$

Dallara, E. S., Kroo, I., and Waitz, I., "Metric for Comparing Lifetime Average Climate Impact of Aircraft," *AIAA Journal*, Vol. 49, No. 8, August 2011.

ATR Inputs

- Varying discount rates, *r*
  - Determines emphasis on short-term vs. long-term effects
  - Source of uncertainty
- Operating lifetime of 30 years



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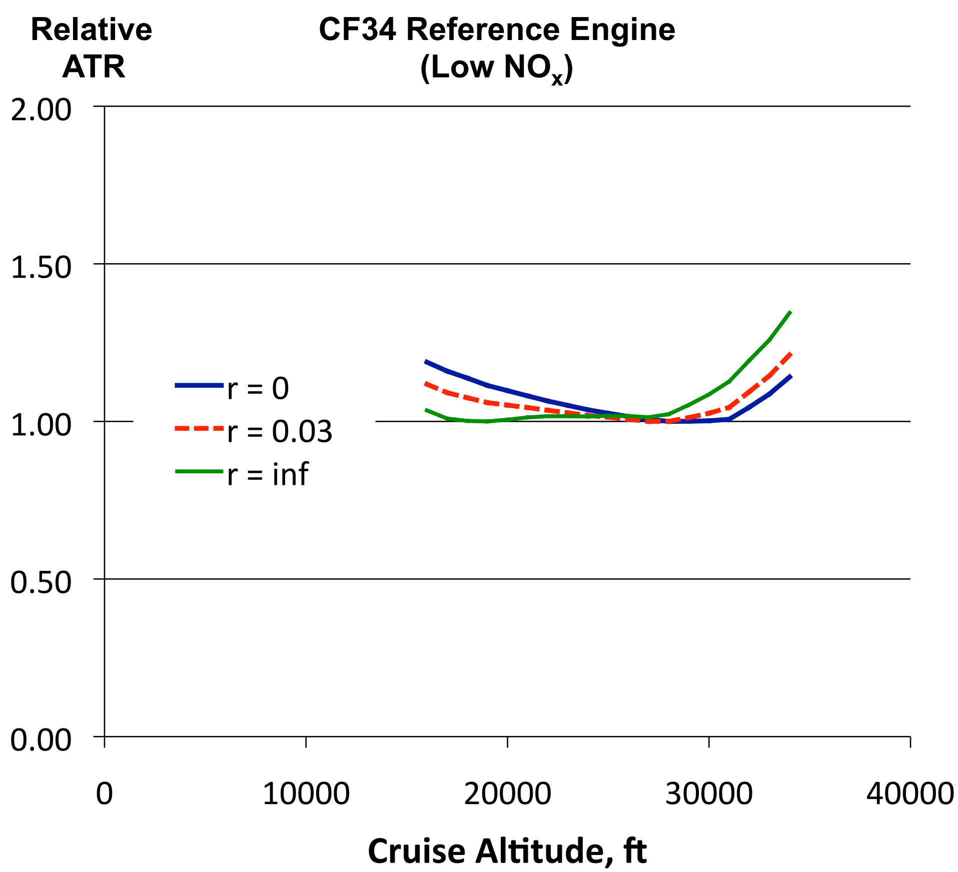
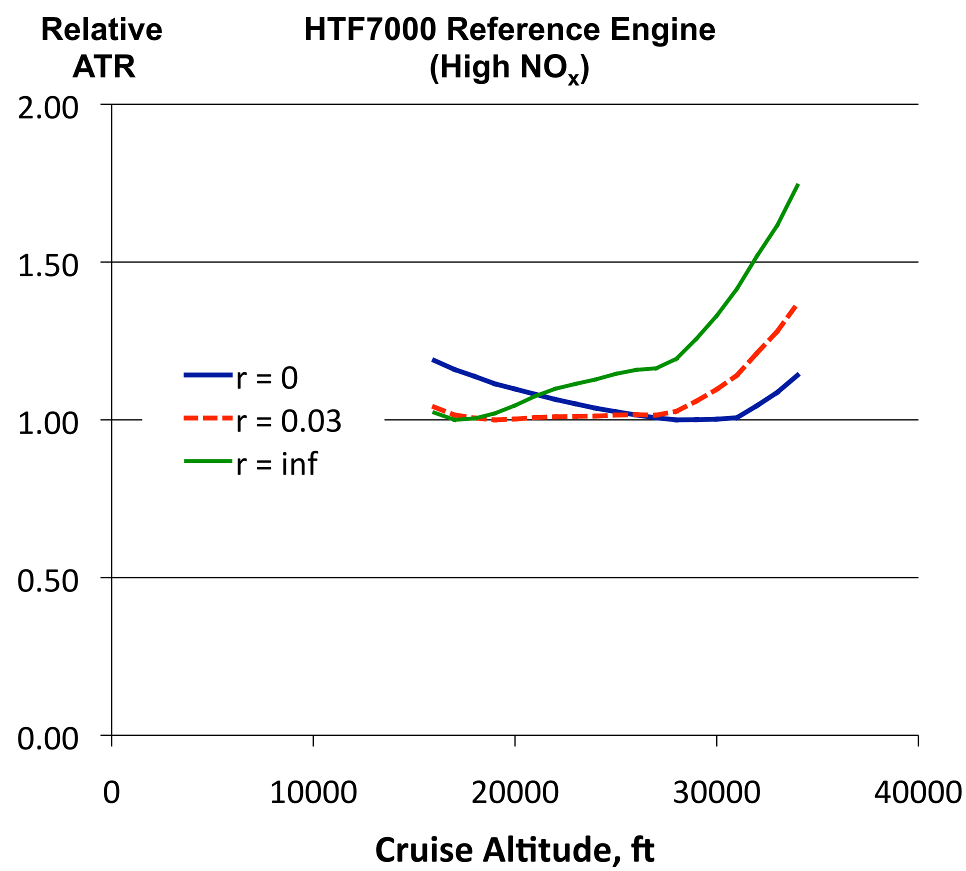
Effects on Tiltrotor Sizing

- Evaluated ATR metric for the 90-passenger tiltrotor design
- Computations using 2 different baseline engines for NOx emissions
- Compared results with minimum fuel burn solution

Discount Rate and Reference Engine





Design Summaries

Physical Characteristics		ATR not Considered	Min ATR $r = \infty$ HTF7000 NOx	Min ATR $r = 0$ CF34 NOx
Overall width	ft	149.6	154.7	150.1
Rotor radius	ft	34.4	35.7	34.5
Wing span	ft	110.8	113.4	111.1
Performance				
Cruise altitude	ft	31,000	17,000	28,000
Cruise speed	kt	302.1	253.0	289.6
Engine max rated power	hp	6,844	7,364	6,893
Empty weight	lb	67,569	71,984	67,986
Max takeoff weight	lb	119,772	128,875	120,632
Mission fuel burn	lb	15,330	18,826	15,659

Takeaway: Targeting low NOx impact favors “low and slow” designs

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Near-Term Schedule

May '13	Jun '13	Jul '13	Aug '13	Sep '13	Oct '13

◇ **MoA meeting at NASA/AFDD**

a) Environmental performance comparisons on a mission profile (90 passenger helicopter)

b) Evaluate flight performance of the tiltrotor and new compound concept

Identify differences in performance models ◇

c) Environmental performance comparisons for the tiltrotor and compound

MoA meeting at ONERA ◇

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