



Engineering, Operations & Technology
Phantom Works

Phantom

Boeing Research and Technology Europe

Can Europe compete as a research location ?

June 2007



Can Europe compete as a research location ?



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe

- **The answer is yes**
- **I'll give you an example: Boeing Research and Technology- Europe**
- **In this presentation**
 - **A general overview about R&D activities inside the Boeing Co**
 - **What's BRTE role**
 - **What we do**
 - **Results conclusions and benefits**

The Boeing Company- Short History



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe

- **Founded in 1916 in Puget Sound, Washington**
- **Became a leading producer of commercial and military aircraft**
- **Undertook a series of strategic mergers and acquisitions to broaden its portfolio that included McDonnell Douglas, the space and defense business of Rockwell Intl., and Hughes Space & Communications, among others**
- **Today positioned as a broad, balanced and global enterprise defining the future of aerospace**

Company's heritage mirrors the history of flight

What we do Today



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe

- Design and manufacture commercial jetliners
 - Boeing 7-series of airplanes leads the industry
 - Offer a broad range of services to passenger and freight carriers
- Produce weapons systems and networking technology
 - World's largest designer and manufacturer of military aircraft
 - Provide services and support to governments worldwide
- Provide satellites and launch vehicles
 - World's largest provider of commercial and military satellites; leading rocket manufacturer; and NASA's largest contractor
- Integrate large-scale systems; develop network-centric solutions
- Provide financial solutions focused on customer requirements
- Develop advanced technology defining the future of aerospace

As a company we connect and protect people



- 
- A light gray world map is visible in the background of the slide, showing the continents and major landmasses.
- 2006 revenue was \$61.5 billion from customers in more than 90 countries
 - International sales were more than 40 percent
 - More than 155,000 employees in 48 states in the U.S. and 67 countries
 - Nearly 6,450 suppliers in nearly 100 countries
 - Research, design and technology development centers and programs in multiple countries
 - Manufacturing, services and technology partnerships with companies around the world
 - One of the largest U.S. exporters

Companies that change and adapt in a rapidly evolving global economy will survive, grow and prosper

Boeing Business Areas



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe

Commercial Airplanes



777



737



767

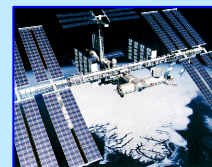
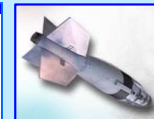
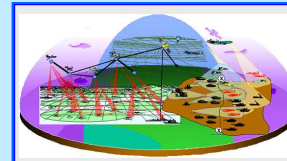
787



747



Integrated Defense Systems



Network and Space Systems

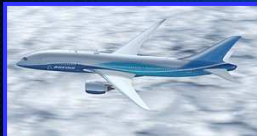


Support Systems



Precision Engagement and Mobility Systems

Phantom Works—Technology and Advanced Concepts



Boeing Capital Corp



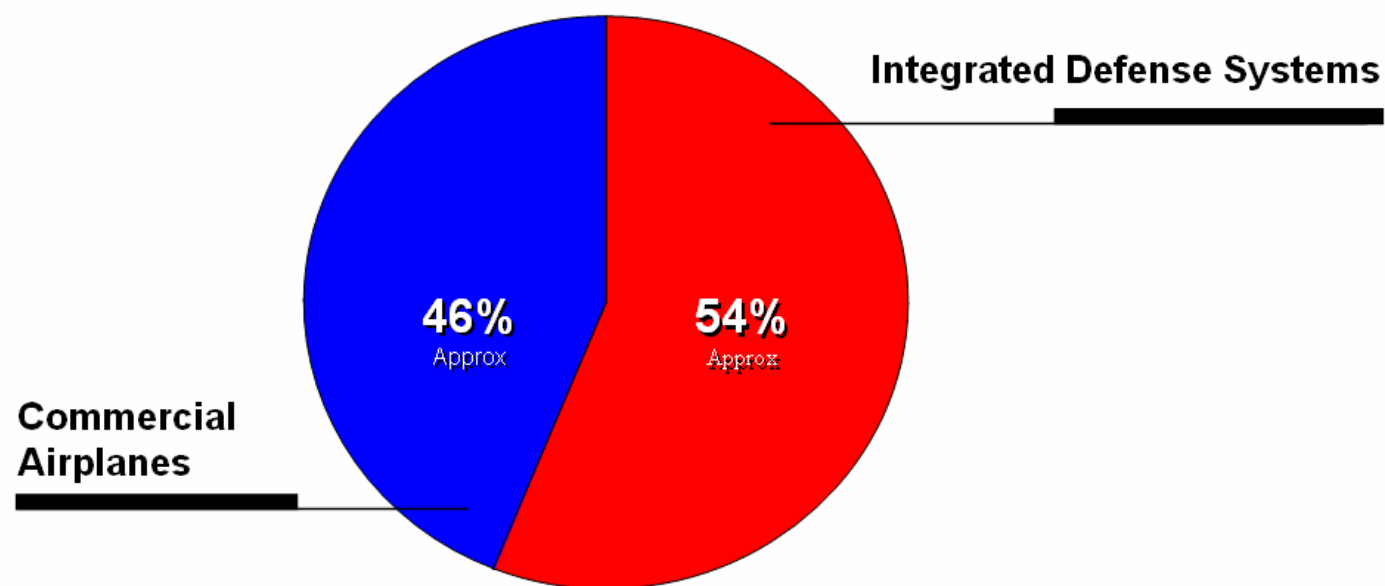
Revenue by Business Unit



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe

Year-end 2006



Total = \$61.5 billion



Phantom Works Vision, Mission & Values

Vision: Innovators and Integrators working across the Boeing Global Enterprise to create the future of aerospace.



Mission: To be the *catalyst of innovation* for the Boeing Enterprise.

Boeing Research and Technology Europe in Phantom Works



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe

Phantom Works Organization



Support Teams



Technology Teams



Enterprise Growth Teams



*Dual-report to Phantom Works and other Operating Group Presidents

Boeing Research and Technology Europe



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe

Phantom Works in Europe

- Created at the start of 2002, first Boeing R&D company created in Europe
- Incorporated under the laws of the Kingdom of Spain: European Union Company
- Wholly-owned subsidiary of the Boeing Company
- Located near Madrid-Barajas Airport



- Technical and Engineering Staff recruited across Europe. Currently six different European nationalities



Engineering and Programs: Environmentally Friendly Air Transport



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe



Environmentally
Friendly Air Transport
Technical Lead

Dr. Nieves Lapeña

Systems Efficiency: Within the frame of the More electrical Airplane, more on-board electrical generation and distribution to power airplane systems for weight advantages and fuel efficiency

Market Drivers: Changing regulatory requirements make environmental issues such as noise, emissions, fuel efficiency and recycling prominent

- **Fuel cells**

Hands-on experience for integrating fuel cells in aerospace applications: design, assembly and test of small experimental manned and unmanned prototypes with fuel cell-based propulsion systems

- **Environmental technologies** Working towards a greener air transport can give Boeing a competitive advantage:

- Environmentally friendly (Cr-free) corrosion protection of aluminum alloys
- Green composite materials for cabin interiors & non-halogenated flame retardants Cd-replacement in sacrificial coatings of high strength alloy steels
- Computational toolset to assess noise/nuisance impact off of traffic simulation results
- IVHM: enhanced microcrack diagnostics of aircraft components and structures
- Nanotechnology (materials) applied to environment

The Fuel Cell Demonstrator



The Fuel Cell Demonstrator Airplane

Project Objectives & Rationale:

Aim: To demonstrate for the first time in aviation history that a **straight level manned flight** can be achieved with **fuel cells** as the **only source of power**

R&D effort: Hands on integration of novel technology on a prototype

- The engine of a motor-glider (Diamond HK36TTC Super-Dimona) was substituted by a PEM Fuel Cell/Li ion Battery **hybrid power source** that drives an **electric motor** rotating a variable pitch propeller
- The Li ion battery is only used to assist during take off & climb
- During cruise (@100 km/h) all the power comes from the fuel cell
- The fuel is compressed hydrogen gas (5,000 psi) stored in a light-weight composite tank

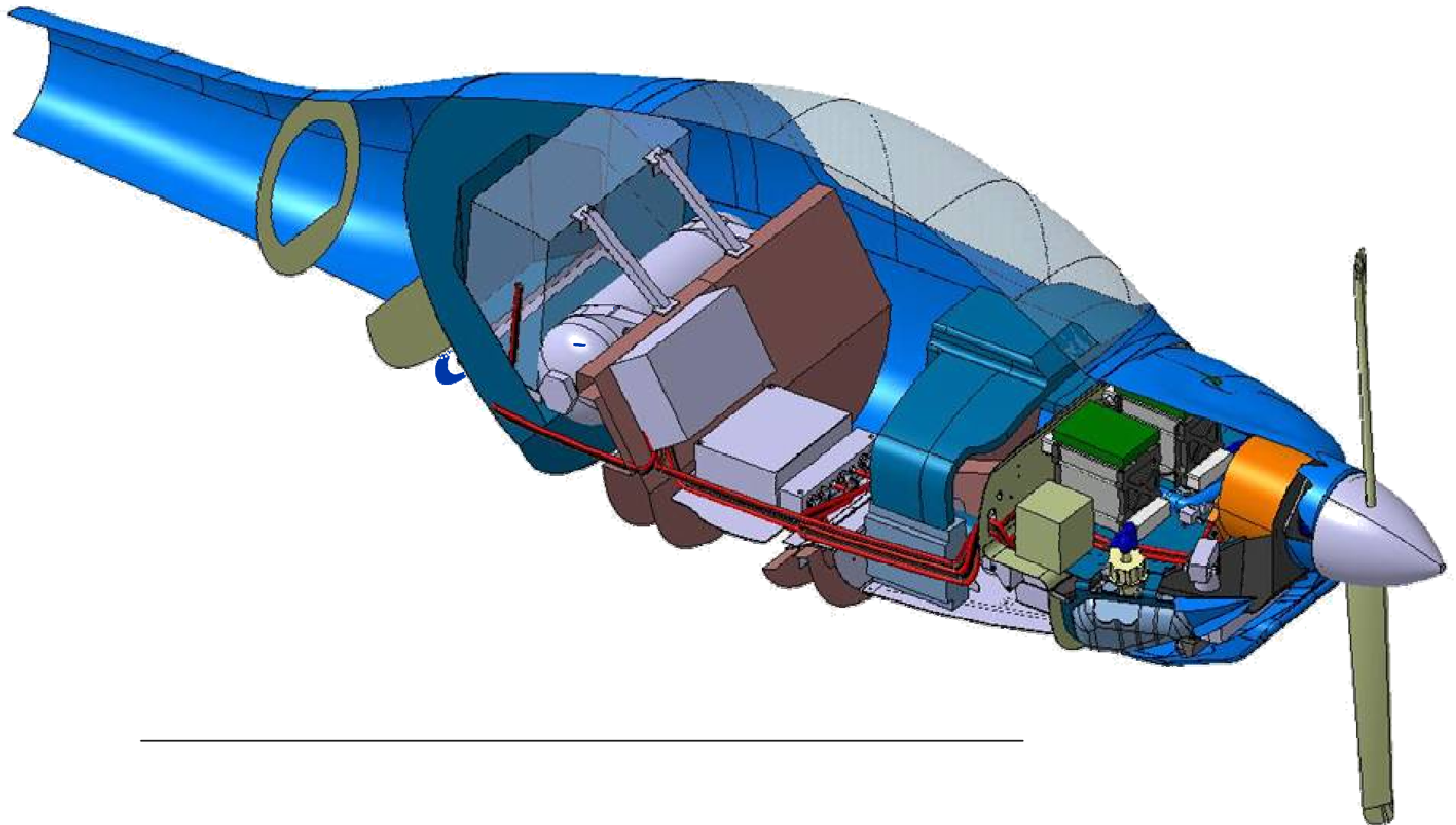
Approach: **Work with European Partners**

- Specifications & tests protocols development for systems acceptance
- Size & weight reduction of all subsystems
- Systems electrical integration and on-board mechanical installation
- Safety requirements developed: flight, hydrogen, electrical system
- If bench tests are successful there will be a public flight demonstration

Benefits of Work: **Develop capability for integration of fuel cell systems in aerospace applications**



Airplane layout



Engineering and Programs: Flight Efficiency



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe



Flight Efficiency
Technical Lead

Dr. Ramón Gómez
Ledesma

Operational Efficiency: Advanced operational procedures (i.e. noise abatement procedures).
Studying ways to relieve crowded airspace

Market Drivers: Changing regulatory requirements make environmental issues such as noise, emissions, fuel efficiency and recycling prominent

- **Advanced operational procedures:**

- Advanced Continuous Descent Approaches (CDA)
- Noise, fuel and time efficient procedures
- Advanced flight guidance

- **Assessment of operational and fuel efficiency:**

- Modeling and simulation of Air Traffic Control (ATC)
- Assessment of fuel consumption, airport capacity, delay and throughput
- Advanced applied statistics to air traffic

- **Assessment of environmental impact of aviation:**

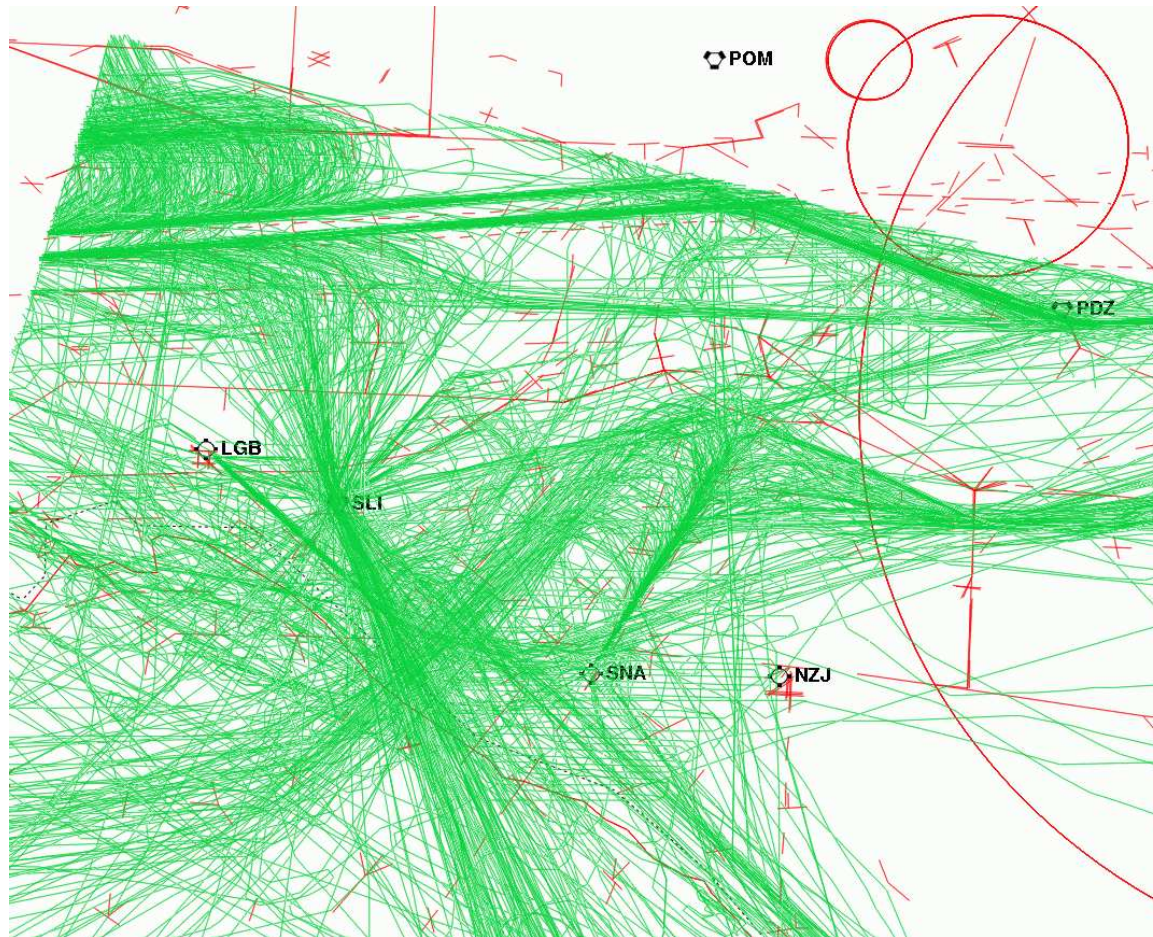
- Assessment of community noise and emissions of aircraft operation

Background: Arrival Traffic in Terminal Area



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe



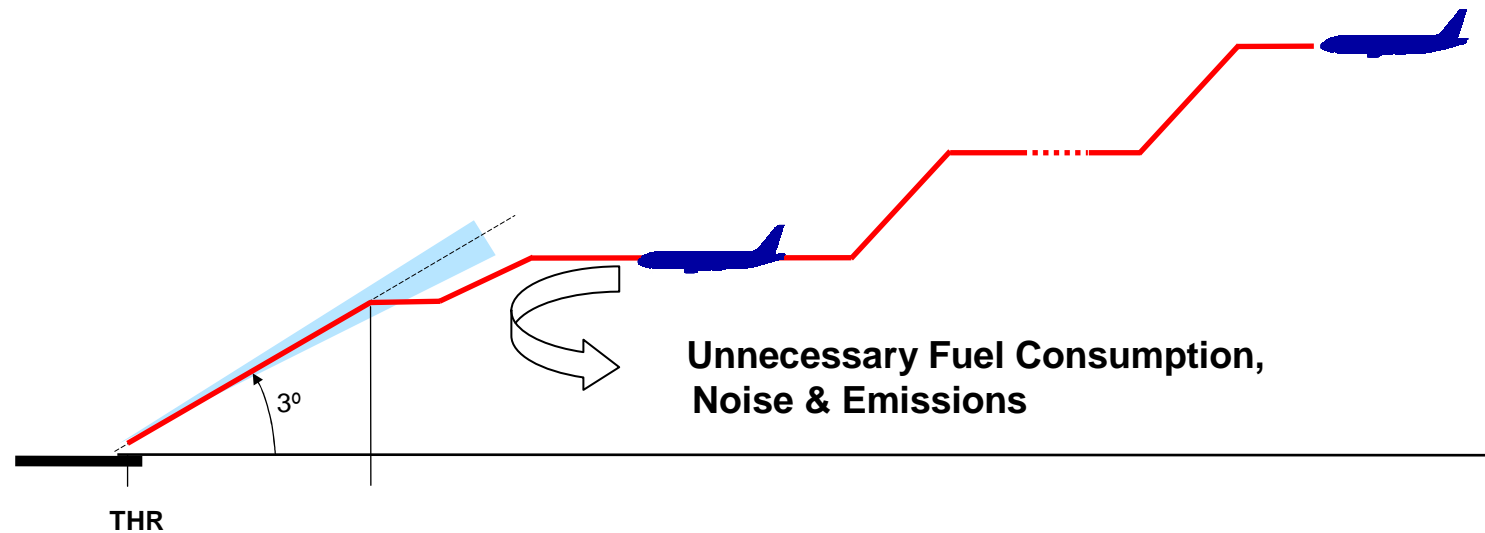
**Dense arrival
traffic in
terminal area
subject to
tactical
corrections**

Background: Step-down Approach Procedures



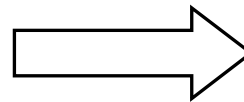
Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe



- **Horizontal Segments:**

- High thrust
- Deployed High-lifting devices
- Low altitude



- **Inefficiencies**

- Unnecessary Fuel Consumption
- Unnecessary Environmental Impact

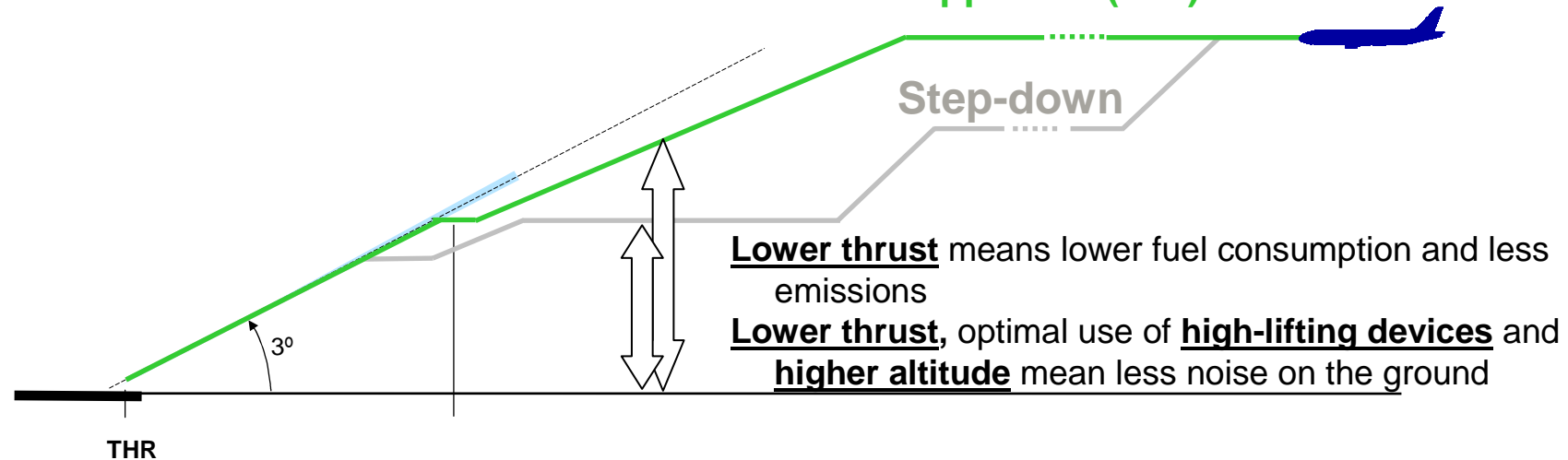
What is a CDA?



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe

CDA= Continuous Descent Approach (Idle)



- CDA is an optimal descent
- Descent is performed in idle thrust (almost) until glideslope interception
- CDAs mean large fuel savings and less environmental impact

CDAs & Numbers: BENEFITS



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe

- Up to **500 lbs fuel** savings per operation
- **30% reduction of NOx** emissions produced below 3000 ft
- Noise benefits between **3.5** and **6.5 dBA**
- **100 secs time** savings in terminal area (TMA/TRACON)

(1) – “Development, Design, and Flight Test Evaluation of a Continuous Descent Approach Procedure for Nighttime Operation at **Louisville** International Airport”. J.P. Clark. Partnership for Air Transportation Noise and Emissions Reduction.

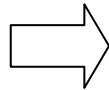
Why are CDAs not Widely Used?



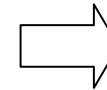
Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe

CDA flights not to receive
ATC tactical corrections
to speed or altitude



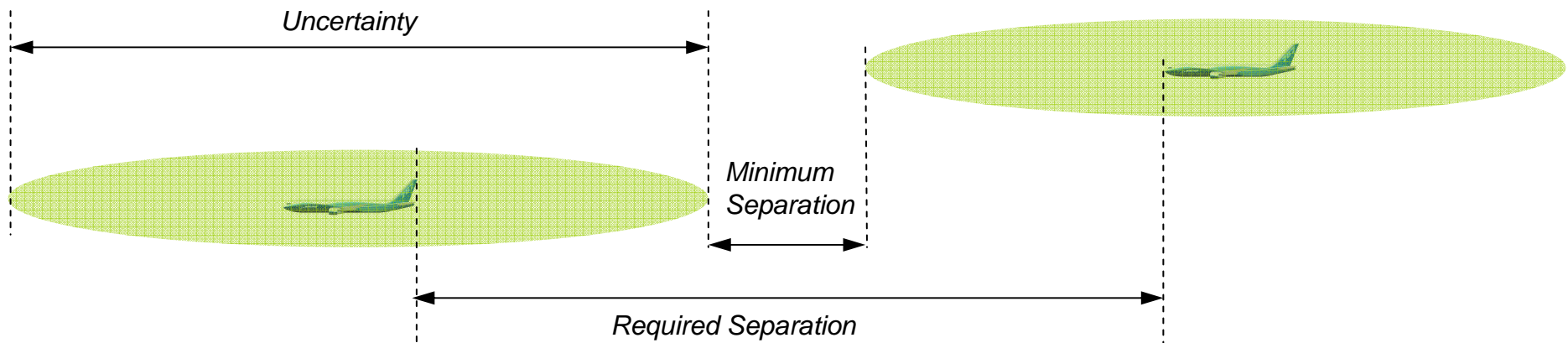
CDA flights at the
expense of the wind



**CDAs have poor
predictability
In horizontal
position / ground
speed**

Airport Capacity Loss

- Larger Separation
- Non-efficient Use of Ground Automation

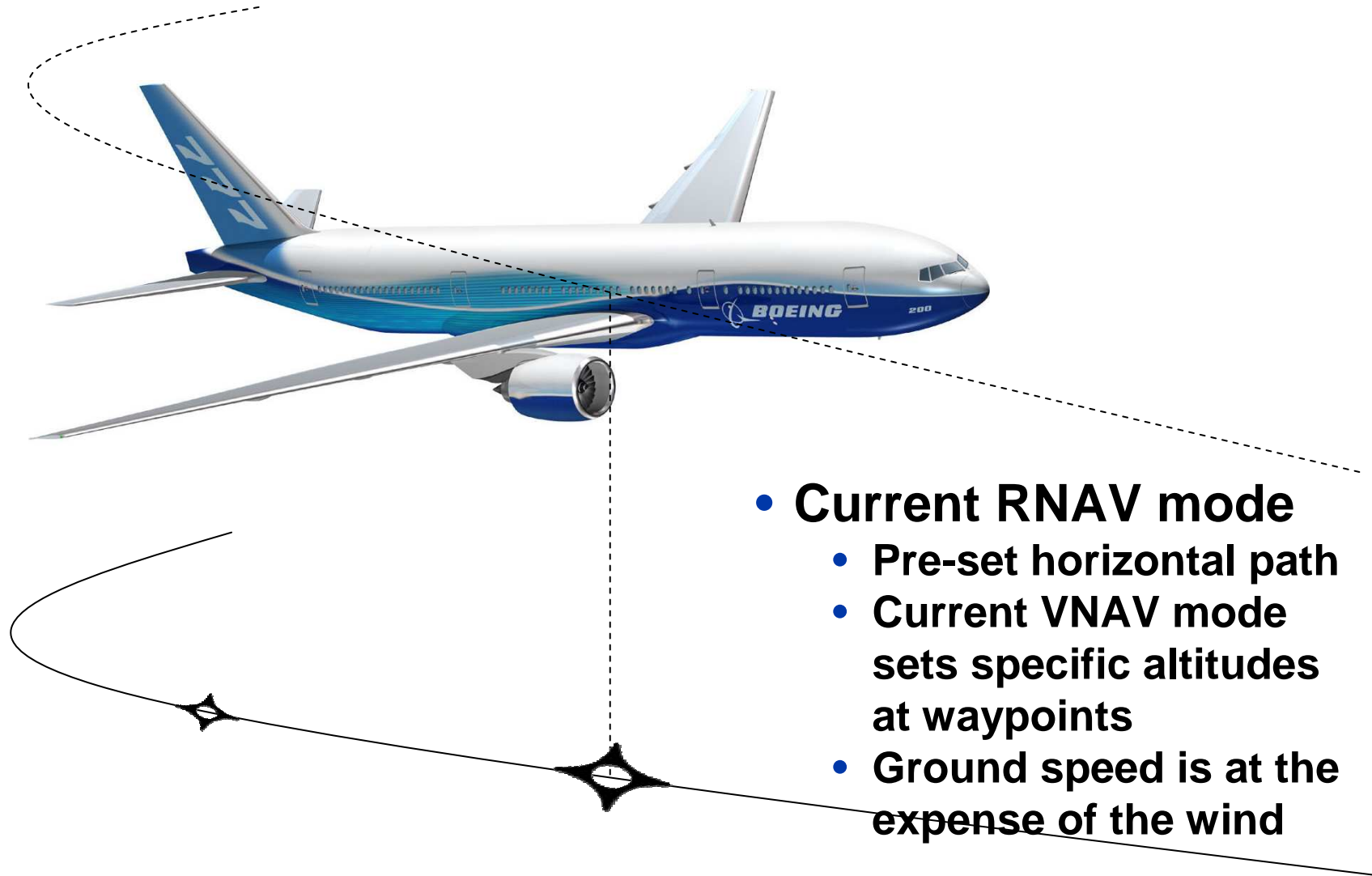


The Key to Predictability: VERTICAL GUIDANCE LAW



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe



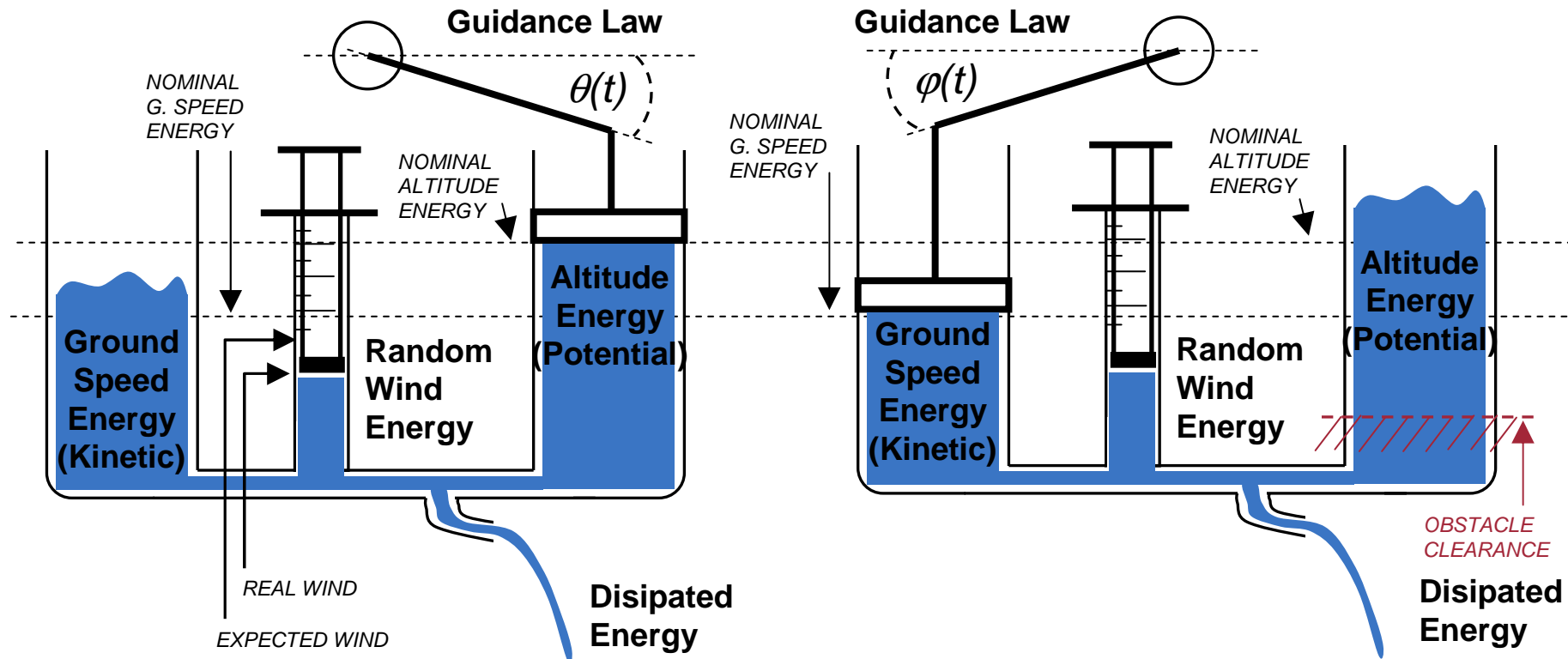
- **Current RNAV mode**
 - Pre-set horizontal path
 - Current VNAV mode sets specific altitudes at waypoints
 - Ground speed is at the expense of the wind

Guidance Law: Energy Management in Idle Descent



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe



- Guidance law based on altitude energy control
- **Current VNAV mode**

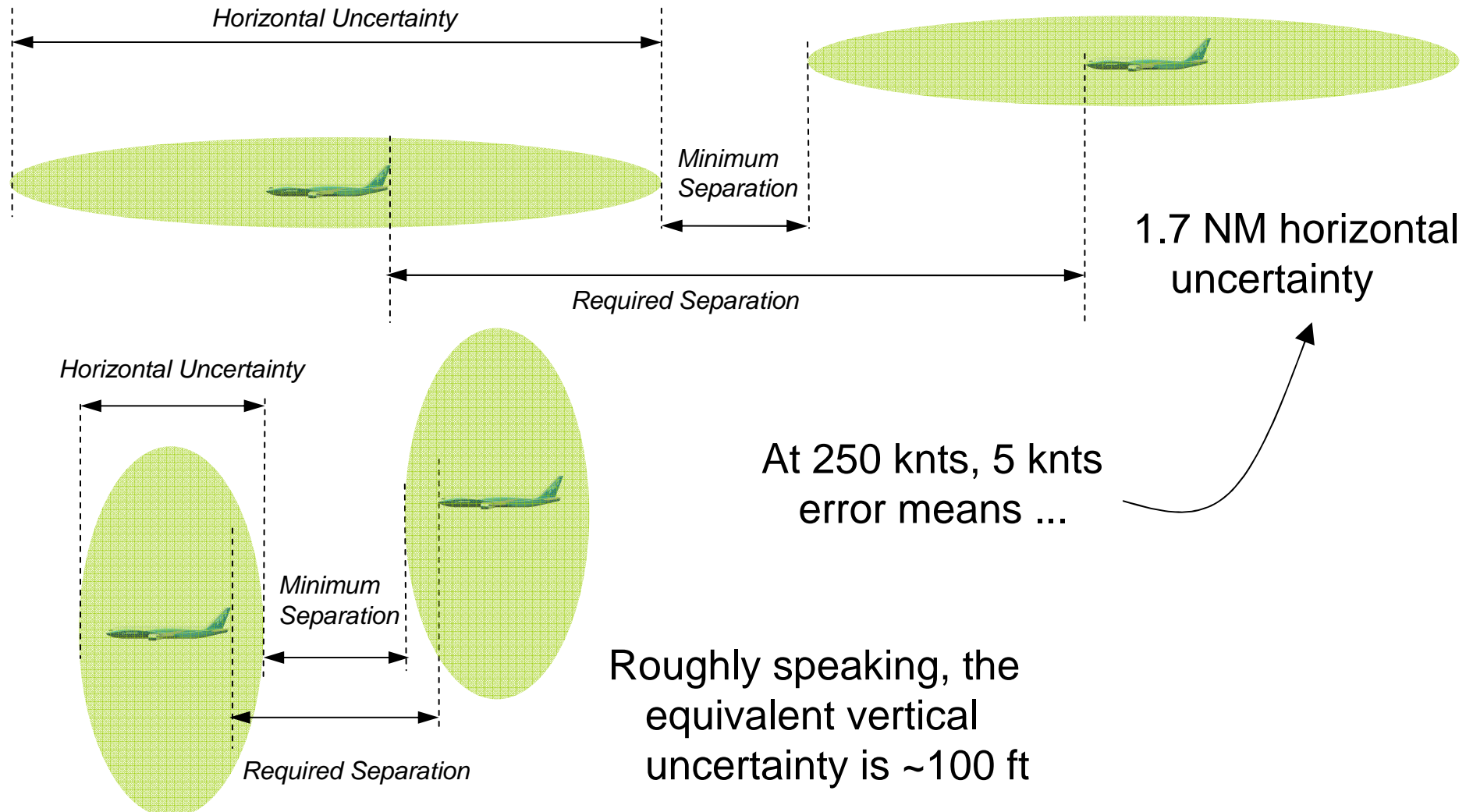
- Guidance law based on ground speed (kinetic) energy control
- **Proposed new mode**

Shift Unpredictability from Horizontal to Vertical



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe



CDA-MP: CDA for Maximum Predictability



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe

- BR&TE has proposed an advanced CDA design based on an innovative vertical guidance law.
- Simulations have shown that BR&TE's CDA design is able to:
 - Keep similar noise and fuel reduction levels as other CDA designs
 - Improve predictability in arrival times up to 90%
- Further research simulations are conducted to validate and test the performance of the design.
- BR&TE's CDA design has filled a patent application.

CDA Type	Time (s)	Fuel (lb)	SEL (dBA)	Lamax (dBA)	Predic (s)
Red. Time	362	+6%	+5%	+8%	22
Red. Fuel	+7%	143	+3%	+5%	24
Red. Noise	+16%	+8%	66	51	31
CDA-MP	+10%	+1%	+2%	+3%	3






Advanced Trajectory
Technologies
Dr. Miguel Vilaplana


Operational Effectiveness and Efficiency: relieve crowded airspace and airports in an efficient, collaborative and fair manner

Optimal Decision Making: distributed deconfliction, autonomous vehicle operations



- **Advanced Trajectory Prediction:**

-  Advanced aircraft modeling and trajectory computation algorithms
-  Multi-purpose trajectory prediction software
-  Trajectory optimization

- **Trajectory Management:**

-  Languages, protocols and simulation tools for air-ground and air-air trajectory negotiation

- **Decision-making Aids:**

-  Conflict detection and resolution tools to support trajectory-based operations
-  Advanced distributed and centralized deconfliction algorithms

Engineering and Programs: Air Transport Economics



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe



Air Transport
Economics Technical
Lead

Javier García

Optimal Decision Making: information packages for effective business decision making: cost benefit analysis and business cases for R&D projects and complex investments

Market Drivers: Changing regulatory requirements make environmental issues such as noise, emissions, fuel efficiency and recycling prominent.

- **Dynamic methodologies, economic models and electronic tools for effective cost benefit analysis, business case development and R&D value assessment.**
- **Advanced representation techniques, sensitivity and probabilistic analysis technologies to support decision making processes.**
- **Risk modeling and simulation: quantitative economic analysis technologies based on advanced computational models.**
- **Market based economic methods addressing environmental issues**

Engineering and Programs: New Programs and Safety



Engineering, Operations & Technology | Phantom Works

Boeing Research and Technology Europe



New Programs and
Safety Technical Lead
Dr. Richard Kennedy

Operational Effectiveness and Efficiency: System modeling, simulation and targeted enabling technology development to realize future aerospace operational concepts.

Optimal Decision Making: Knowledge and decision analysis tools for risk management in distributed and virtual organizations.

Market Drivers: Development of next generation safety and human factors approaches to enhance safety and operability of aircraft and ATM systems.

- **UAS in Civil Airspace Models, Reduced Aircraft Separation Minima for ATM, Flight Data Analysis Software, Multi-Modal Interfaces for UAS Operations.**
- **Analyst Associate for Maintenance Resource Allocation, GRID Computing Network in a Collaborative Work Environment, Security Case Analysis Methodology.**
- **Human Performance Uncertainty Safety Assessment Tools, Flight Operations Safety Survey, ATM Safety Culture Measurement Technique.**



For the Company doing R&D in Europe

There is a real possibility to create knowledge (Patents-Tech Transition-Breakthroughs)

Facts

R&D aligned with the European culture & way of life

Company products will take this advantage in a significant market

For the Company and the European based Industrial Community

European EU-driven-FP provides great collaborative R&D opportunities

Facilitates global R&D networking and market understanding

For the European Society

Creates knowledge for capturing knowledge

