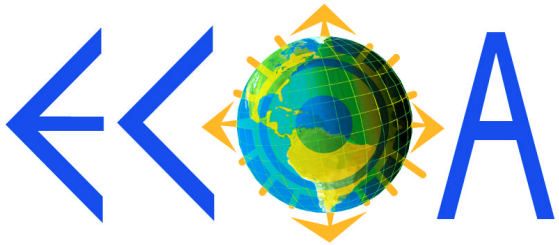


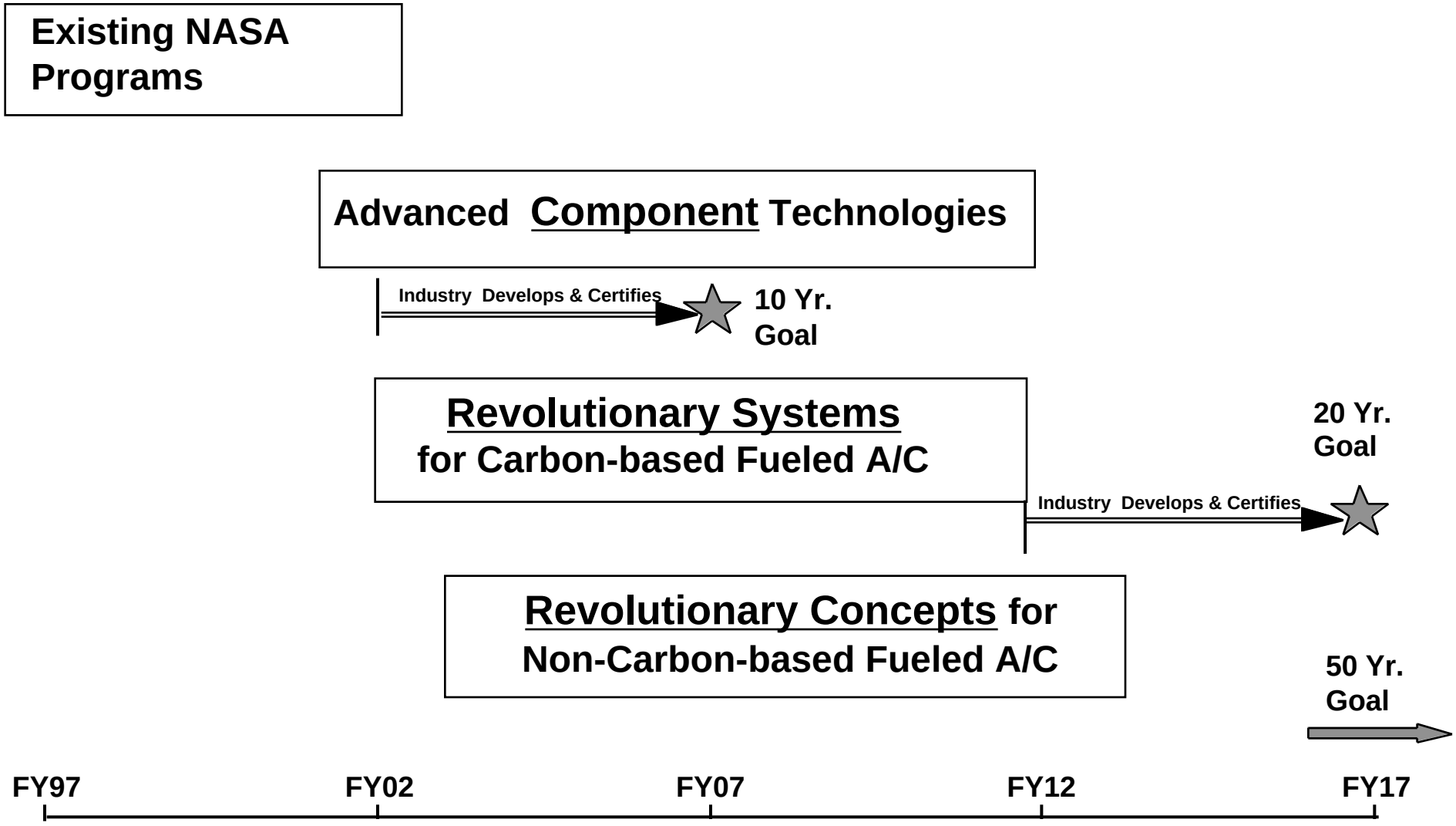
Emissions Breakout Summary

John Rohde

NASA Lewis Research Center

May 21, 1998

Potential Environment Emissions Program Overview



Emissions Breakout Session - Near-Term Propulsion

ENABLING CONCEPTS

- Ultra High Bypass Propulsor
- Ultra High Pressure and Temperature Core

ENABLING TECHNOLOGIES

- Hi-Temp Fuel Systems
- Intelligent Controls
- Ultra-Low Ns Turbomachinery
- Non-Traditional PAI
- Highly Loaded T/M Design Methods
- Disk, Casing Materials (High OPR)
- Advanced Cooling Schemes/ Closed Cycles
- Characterization of Aerosol / Particulate
- Ultra Low Emission NOx Combustor
- Hot Section Modeling (SO_2 & SO_3)
- Active Combustor Control
- Sensing & Diagnostics (esp. hot sections)
- Alternate Fuels (Low C/H ratios, Low Sulfur, Fuel Additives)

Emissions Breakout Session - Mid-Term Propulsion

ENABLING CONCEPTS

- Advanced Cycles (Combined, Topping, Wave Engines, Pulse Detonation)
- Variables Cycles
- Electric Motor-Driven Mini-Fan
- Smart/Active/Adaptive Engine
- Hybrid Engine Systems
- H/C Fuel Cells & Hydrogen Fuel Cells
- Core-Driven Electric Generators

ENABLING TECHNOLOGIES

- Advanced Cooling Schemes/ Closed Cycles
- Coatings/Ablation Effects
- Metal/Ceramic/Polymer Matrix Composites
- Advanced Gearbox /Transmissions
- Intercooling
- Aspirated Fan
- MEMS Transducers and Valves
- Alternate Fuels (Low C/H ratios, Low Sulfur, Fuel Additives)
- Catalysts
- Advanced Numerical and Experimental Tool
- Advanced Facilities

Emissions Breakout Session - Far-Term Propulsion

ENABLING CONCEPTS

- H/C Fuel Cells & Hydrogen Fuel Cells
- Batteries
- Microengines
- Propulsive Wing

ENABLING TECHNOLOGIES

- Micro Adaptive Flow Control
- Renewable Hydrogen
- Superconductivity

Emissions - Airframe

- Structures &Materials
- Aerodynamic Performance
- Flight Systems
- Aircraft Systems
- Advanced Concepts

Emission - Airframe
Structures & Materials

- Composite Wing (S)
- Composite Fuselage (L)
- Aeroelastic Tailoring (L)
- Lt. Wt. Landing Gear (S)
- Storage for Alternate Fuels (VL)
- Lt. Wt. Alloys (L)
- Noncircular Pressure Structures (L)
- Replace Windows with Non-Penetrating System (L)
- Interior Noise/Thermal Insulation (S)
-

Emission - Airframe
Aerodynamic Performance

- Skin Friction, Induced Drag, Wave Drag reduction (S)
- Laminar Flow Control (VL)
- Lt.Wt. High-Lift Systems (L)
- High B.P.R. Integration (S)
- Advanced nacelle (L)
- Active flow control (L)

Emission - Airframe
Flight Systems

- Antennae (Lower Drag/Wt) (S)
- Real Time Configuration (L)
- Emiss. Opt. Flight path (L)
- Integrated Avionics (L)

Emission - Airframe
Aircraft Systems

- Air Conditioning System (L)
- Electric Airplane [Power-by wire] (S)
- Hydraulic Systems (S)
- Cabling infrastructure [Fiber Optics] (S/L)
- Passenger Amenities [Galleys, Lavatories] (L)

Emission - Airframe
Advanced Concepts

- BWB, Box Wing, Strut-braced wing (VL)
- Oblique Wing (VL)
- Laminar Flow (L)
- Fuselage Concepts to maximize passenger count (L)
- Slatless/Flapless Adaptive Wing (VL)
- Neural Control (VL)
- Biological Mimitics Structures (VL)

Revolutionary Concepts

AIRFRAME

2017

- High-, Low-Wing
- Single or Double-Bubble Fuselage
  - Composite Structures
  - Low Wt. Subsystems
  - Integrated Avionics
  - Improved Aerodynamics & Hi-Lift Systems

2017+

~~2047~~

- Blended Wing Body
- Box Wing
- Strut Brace
- Storage for Alternate Fuels

PROPULSION

2017

- Distributed Propulsor
- Smart Adaptive Engines (MEM, Aspirative)
- New Cycles

2017+

~~2047~~

- Microengines
- Batteries
- Fuel Cells
- Alternate Non-Carbon Based Fuels

Potential Environment Emissions Program Level I Roadmap

Existing NASA Programs

Advanced Component Technologies for JP-type Fueled A/C

- Propulsion
- Airframe
- Assessment and Integration
- Ground and Flight Operations

Industry Develops & Certifies → 10 Yr. Goal

Need PAI System Studies to Define Revolutionary Concepts for the Airframes and Engines

Revolutionary Systems for Carbon-based Fueled Aircraft

- Propulsion
- Airframe
- Assessment and Integration
- Ground and Flight Operations

Industry Develops & Certifies → 20 Yr. Goal

Revolutionary Concepts for Non-Carbon-based Fueled Aircraft

Work Enabling Concepts/Technologies:

- Propulsion
- Airframe
- Alternate Fuel
- Integration and Ground Operations

→ 50 Yr. Goal

FY97 FY02 FY07 FY12 FY17

Detailed System PAI Studies Needed to Understand Revolutionary

Revolutionary for Carbon Based Fuels System Concepts

AIRFRAME

2017

- High-, Low-Wing
- Single or Double-Bubble Fuselage

2017+ Higher Risk Concept

- Blended Wing Body
- Box Wing
- Strut Brace

PROPULSION

2017

- Distributed Propulsor
- Smart Adaptive Engines (MEMS, Aspirative)
- New Cycles
- Batteries

Revolutionary for Non-Carbon Based Fuel System Concepts

- Hydrogen Blended Wing Body
- Lithium Blended Wing Body
- Hydrogen Fuel Cell
- Microengines
- Lithium Fuel Cell

Emissions Breakout Session
Combustion

ENABLING CONCEPTS

- Multi-Staged Combustor
- Advanced cooling
- Variable Geometry Combustor
- Post Combustor Chemistry
- Control Aerosols/Particulates
- Engine/Combustor Scavenging Sys.
- Water Augmentation
- Alternate Fuels
  - High H/C Ratio
  - Alcohol
  - Methane
  - Hydrogen
  - Additives

ENABLING TECHNOLOGIES

- Cooled Ceramic Liner
- Idle Emissions Reductions
- Catalytic Pilot Combustor
- Innovative Fuel Mixers
- Ceramic Liner
- Designer Fuels
- Catalytic Combustor
- Combustor Size Effects
- Analytic and Experimental Tools Development
- Laminates
- Advanced Flame Stabilization

Atmospheric Assessment and Modeling

- Instrument Development
- Local Air Quality Models
- Assessment of Fuel Additives Climate Effect
- Chemistry & Emissions Evolution Measurements/ Models Downstream of Combustor
- Near Plume Measurements for radical species & aerosol precursor species
- Transport Models
- Continued Effort in operational scenario models
- Correlation of Sea level to cruise NOx

Emissions Breakout Session Ground and Flight Operations

ENABLING CONCEPTS

- Reduced minimum fuel requirement (Long)
- Advanced Emission Minimization Procedures (Short & Long)
  - optimized trajectory
  - minimum loiter strategy
  - meteorological dispersion consideration
- Pilot/Controller workload Management Techniques (Long)
- Fuel efficiency formation flying (Very Long)
- Alternative taxi power (Long)
- One Engine Taxi (Short)
- Towed Taxi (Short)

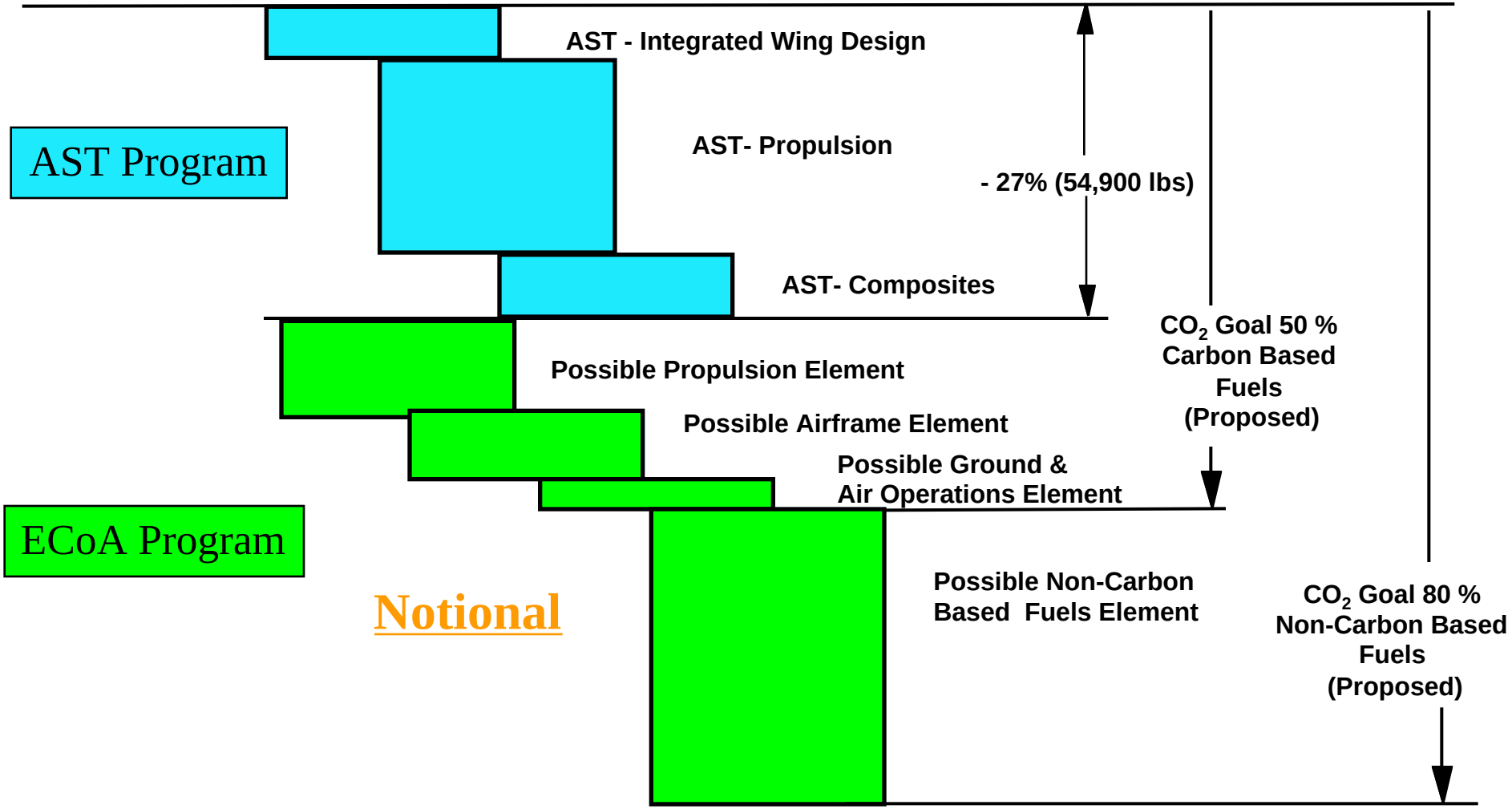
ENABLING TECHNOLOGIES

- Integrated controls for optimal emissions ops; airframe configuration management (All)
  - optimization of existing systems (Short)
  - full variable geometry aircraft (Very Long)
- Emissions source monitors (Short)
- extended free flight technologies (Long)
- Real Time Engine Health monitoring for minimum emissions (Short)
- Meteorological dispersion advisor (Long)
- Additives to reduce impact of fuel dumping (Long)
- Real time energy management for approach and departures (Short)
- Minimum fuel consumption air traffic mgmt tools (Extended collaborative decision making) (Long)
- Formation precision FMS and position info (Very Long)
- Extended surface traffic management tools (Long)
- Powered landing gear (Long)

Environmental Program CO_2 Emission Reduction Waterfall

LONG HAUL/MEDIUM CAPACITY CONVENTIONAL SUBSONIC TRANSPORT

2-Engine, 325 Passengers, 6500 nmi Design Range, 10000 ft Field Length

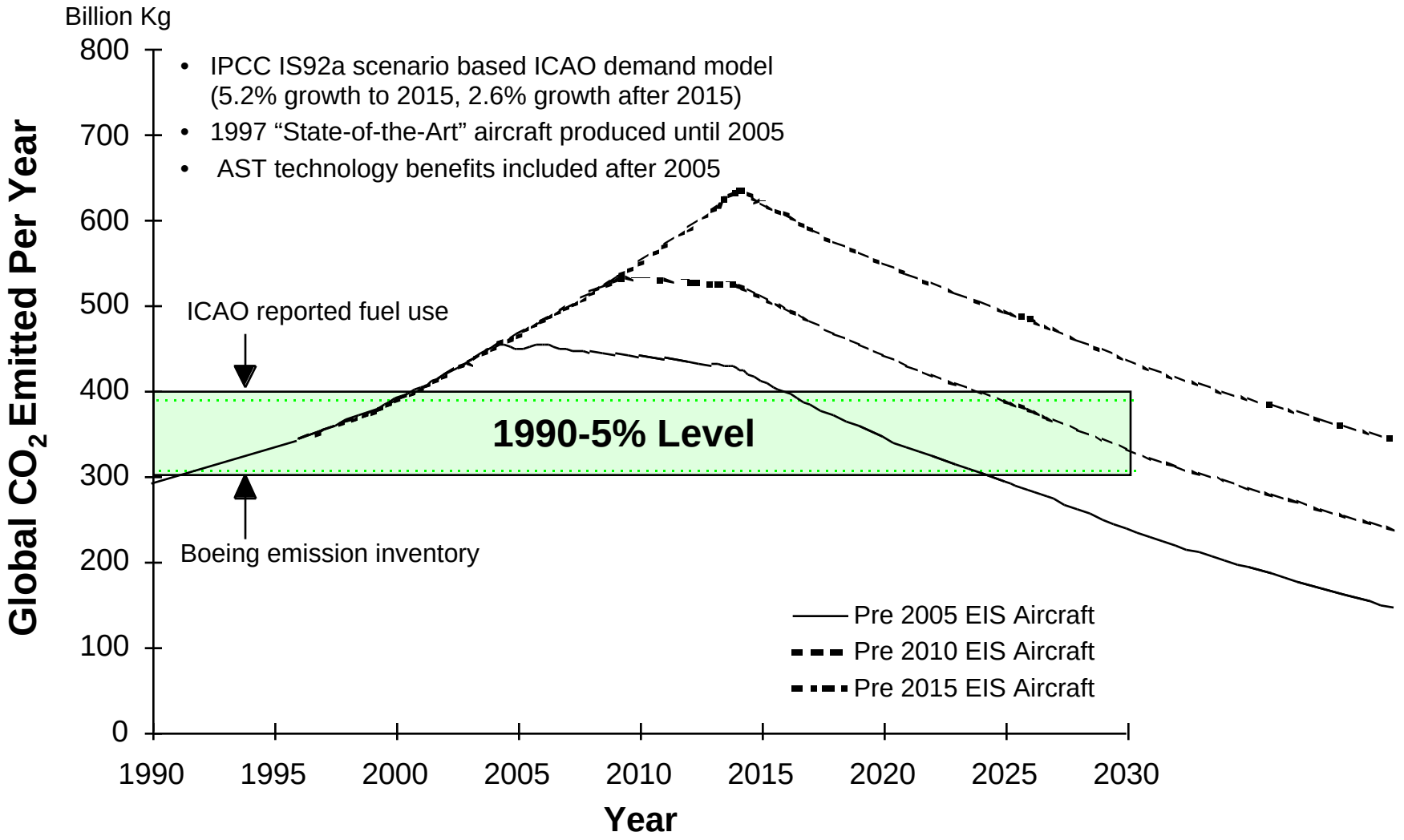


STATEMENT OF PROGRAM

CO_2 EMISSIONS OUTCOME :

By 2002 demonstrate technology readiness to reduce the average fuel burned of new aircraft by at least 25% with possible introduction into service after 2007, and by 2012 demonstrate technology readiness to reduce the average fuel burned of new aircraft by at least 50% for carbon fueled aircraft with possible introduction into service after 2017. Also, continue to work non-carbon fueled aircraft to seek additional CO_2 or fueled burned reduction of 80% in 50 years.

Emissions from Aircraft Produced Before 2015



Effectiveness of advanced technology in reducing total CO_2 emissions will be limited by older aircraft in fleet

STATEMENT OF PROGRAM

NOx EMISSIONS OUTCOME :

By 2002 demonstrate technology readiness to reduce both landing/takeoff and flight conditions NOx emissions by at least 67% for future large and regional engines with possible introduction into service after 2007, and by 2012 demonstrate technology readiness to reduce both landing/takeoff and flight conditions NOx emissions by at least 80% for future large and regional engines with possible introduction into service after 2017

STATEMENT OF PROGRAM

NEW EMISSION CONCERN OUTCOME :

Address new emission concerns by characterizing /reducing emission levels of aerosols, particulate, and other minor trace species to their lowest practical limits.

Some of the Issues/Concerns Raised (All Issues Will Be Recorded)

- Re-visit Historical Revolutionary Concepts
- Redo/Re-visit Battery Concepts
- Establish w/DOE (Hydrogen Generation)
- “Modular Transport” concept? (Airframe Systems)
- Flight speed optimization (To Airframe Systems)
- Need to identify GCC vs. LAQ vs. OD benefits/concepts
- What if TRL 6 - 5 yrs is not consistent w/industry experience (ie, EEE, ECCP); NASA and Industry timeframes need to converge
- Economics of retrofit must be assessed
- Emissions vs operating conditions - not necessarily straight line over entire range e.g. CO2/NOx variation

Some of the Issues/Concerns Raised (All Issues Will Be Recorded)

- Optimum CO_2 cycle not necessarily optimum NOx cycle
- How do we address disconnects between the atmospheric & aero communities? Recommend development of Technical Committee to communicate between both communities
- Need current information to project where technologies need to go
- What emissions are coming out of the engines?
- Near term emissions trade decision needs to be made
- Are the pillar goals appropriate?
- Should we develop new capabilities to address local (airport) health issues