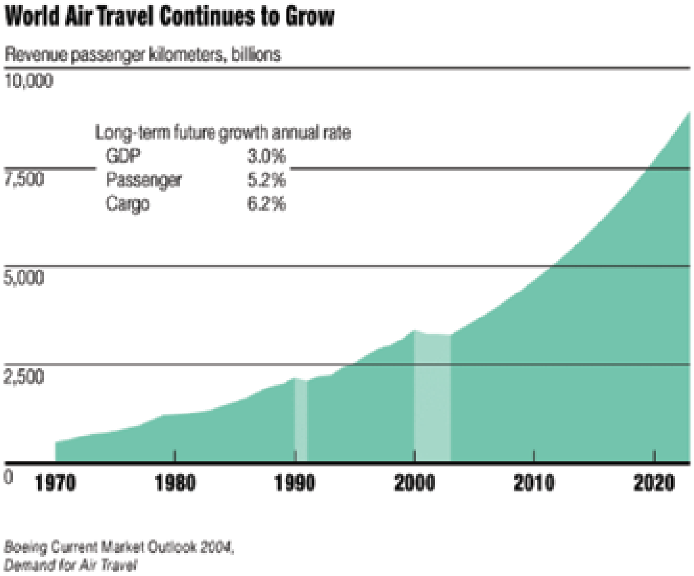
Energy-Efficient Air Transportation

A satellite photo shows the dense coverage of airplane contrails across the Southeast U.S. sky. Contrails may contribute to global warming.

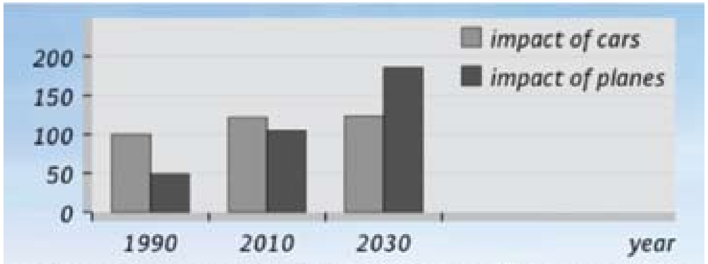
Efficient, robust, safe, and environmentally aware air traffic management is critical to the functioning of the global economy. In the U.S., aviation is responsible for 5% of GDP and an estimated 12 million jobs. The system is already being strained by the current levels of demand, weather disruptions, and volatile fuel prices. Domestic air traffic delays in 2007 cost U.S. airlines an estimated $19 billion in direct operating costs, and the cost to the U.S. economy is estimated at $41 billion. The number of operations in this already congested environment is expected to increase two- to threefold by 2025, posing a new challenge to the effective functioning of the U.S. air traffic system. With similar concerns worldwide, major delays and large economic and environmental impact are inevitable on a global scale unless significant actions are taken. Control and optimization will be key technologies.

Energy and Environmental Impacts

Despite dramatic increases in aircraft fuel efficiency, the energy requirements of the air transportation system are expected to more than double in the next three decades. Each long-distance flight of a 747 adds about 400 tons of CO_2 to the atmosphere (about the annual per capita emissions in Europe for heating and electricity). Although aviation now consumes only about 13% of transportation-related energy, it is growing rapidly, and the climate impact of emissions at altitude has been estimated to be two to four times greater than reflected by the percentage of carbon emissions. In addition, local noise and emissions and land-use restrictions are limiting the capacity of the transportation system in many areas of the world.



"Air travel is the world's fastest growing source of greenhouse gases" (Friends of the Earth). The impact of aircraft may exceed that of cars in the next two decades.



Worldwide comparison cars and planes, impacts on climate change. Scale: cars in 1990 = 100. Source: OECD 2000

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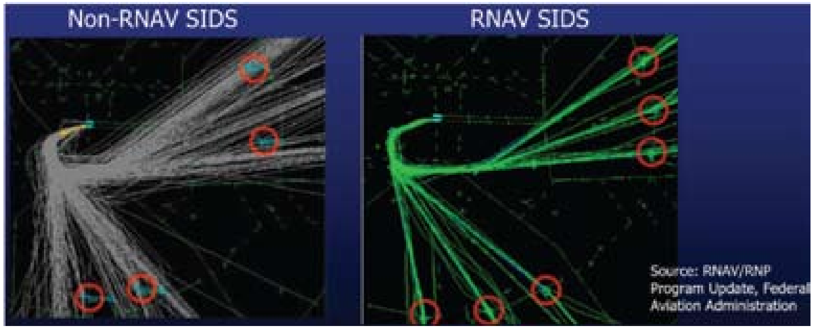
A Distributed, Large-scale, Multi-objective Control Problem

Active flight management of the entire air transportation system will allow for more reliable operations while respecting constraints on noise and emissions. This concept will involve real-time, massively distributed sensing and modeling to enable path replanning and trajectory optimization. By using local sensing data from other aircraft in a given region of airspace, an aircraft could potentially decrease its fuel burn and emissions by dynamically optimizing for its flight altitude and trajectory. It may also be possible to reduce the formation of contrails by dynamically rerouting to avoid regions of the atmosphere that are saturated with ice. Potential tradeoffs exist between objectives such as fuel burn, operating costs, delays, and system throughput. Multi-objective control techniques for routing are needed that use distributed sensing on board aircraft to simultaneously optimize these various objectives while ensuring safety in the airspace. Market-based schemes are also being envisioned that depend on the impact each airline's operations have on the environment, both individually and through information sharing, to help achieve greener air traffic operations.

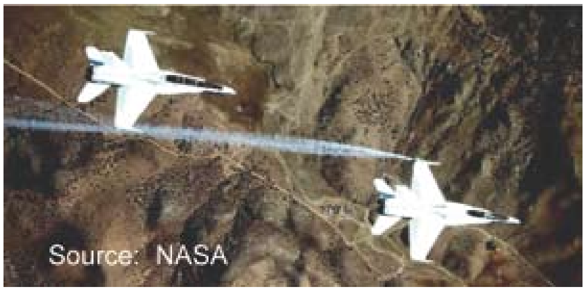
Airports form the critical nodes of the air traffic network, and airport capacity drives overall system capacity. The main constraining factor on airport capacity is the minimum separation mandated between aircraft takeoffs and landings to avoid wake turbulence. Current separation requirements are based on maximum takeoff weight and tend to be overly conservative. Integrating onboard sensors and local weather factors with arrival/departure scheduling algorithms will result in improved runway throughput and decreased delays, fuel burn, and emissions. The same can hold true for optimized airport surface movements using real-time information sharing.



Area navigation (RNAV) standard instrument departures (SIDS) provide structured "lanes" to en route airspace. Benefits include more departures per hour per runway, reduced delays during peak demand, and reduced air/ground voice communication. Annualized benefits are estimated at $39 million for Atlanta International Airport.

Innovations:

- Typical aircraft approaches into airports require a series of short descent and level flight portions. Continuous descent approaches (CDA), which remove the level flight portions, are much more fuel efficient, require less thrust, and reduce engine noise. Noise levels are typically reduced by 5 dB on the ground, and over 4 minutes and almost 400 liters of fuel are saved per approach. Although CDAs are now being implemented in the U.S. and exist in much of Europe, they currently are not used during arrival rushes; more advanced automation is needed to enable conflict-free CDAs in dense traffic.
- Closely spaced parallel approaches could be realized with automated collision avoidance algorithms based on onboard sensing and automatic control. Such approaches would allow parallel runways to be used under more conditions than today, thereby increasing airport capacity.
- Birds achieve significant energy savings by flying in close formation. Formation flight is also being explored for aircraft with similar motivations. Large induced drag, emissions, and noise reduction may be possible.



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