



Performance Based Navigation (PBN) The Science and Application to High Density Terminal Arrivals

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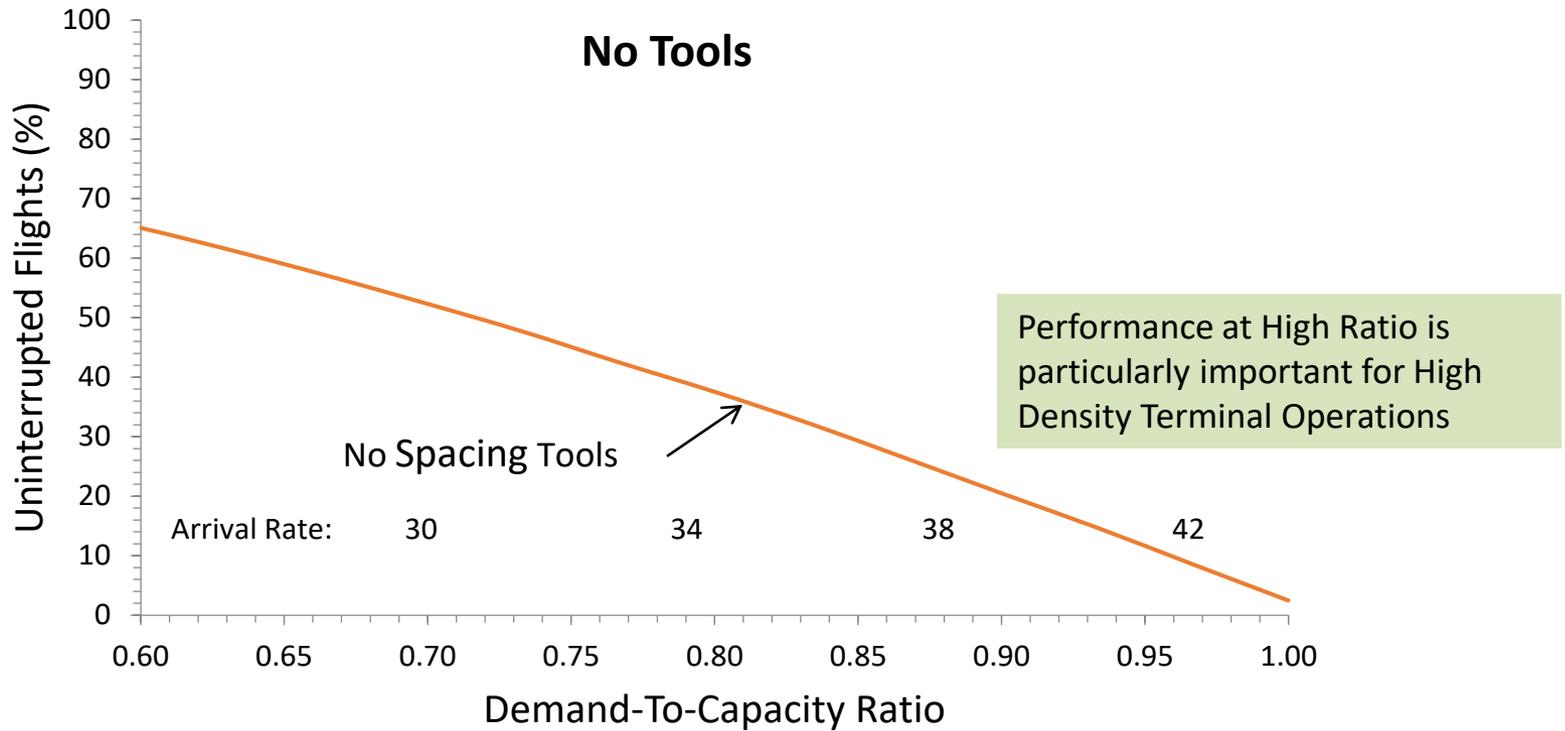
A Fundamental Air Traffic Management Concept



- As Demand approaches Capacity, Efficiency is negatively impacted
- What are some of the impacts of the efficiency loss?
 - Passenger/cargo delays
 - Schedule conformance reduction along the flight plan
 - Increased fuel (burned and reserves)
 - Flight plan deviations
 - Increases uncertainty and limits optimization of strategic objectives
 - One example metric is:
 - Uninterrupted Flights: The percentage of flights that do not require an instruction to change the heading, speed or altitude of the aircraft



Efficiency (as Uninterrupted Flights) vs Demand-To-Capacity Ratio



Assumes Area Navigation/RNAV Optimized Profile Descents for arrival phase



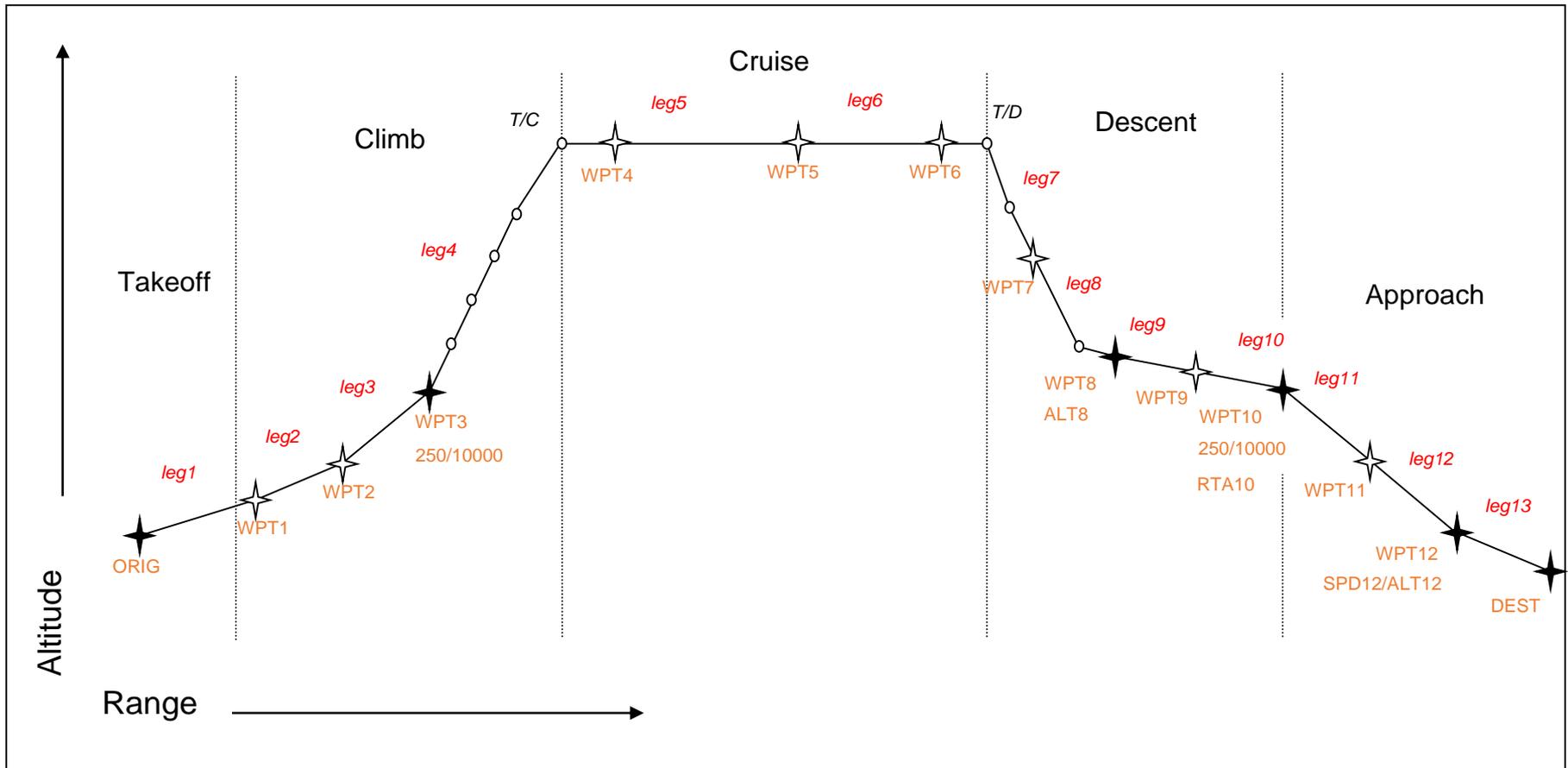
Motivation



- PBN is an important mitigation for the efficiency loss
- PBN establishes better defined routes using a series of waypoints with associated speed and altitude constraints as needed
- The routes are defined by a team of local community members that includes, at a minimum, traffic flow managers, air traffic control managers, operators, and manufacturers
 - Aircraft must be able to reliably conform to the routes so operator and manufacturer input is critical
- Once the routes are defined, they are published and incorporated by systems integrators into ground and airborne automation systems
- Automation systems can use the published routes to build partial or full trajectories that can be used to improve the precision and accuracy of air traffic management systems



Continuous Routes



Profile of a gate-to-gate trajectory



Brief Example of Continuous Route Implementation for Arrivals in the NAS



- Denver International Airport
 - Published RNAV Standard Terminal Arrivals (STAR)
 - Published Instrument Approach Procedures (IAP)
 - IAPs connect all STARs to all RWYs in both North and South flow configurations
 - Enables a full trajectory to be well estimated from En-Route /Cruise all the way down to the RWY

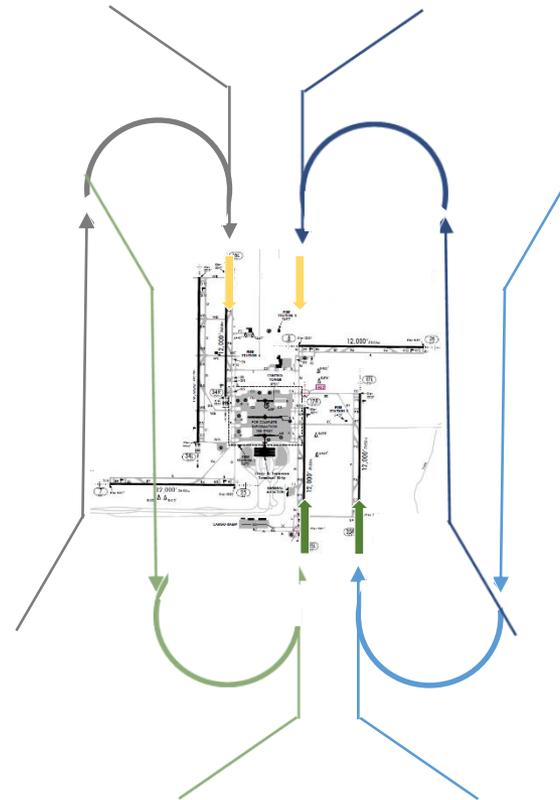


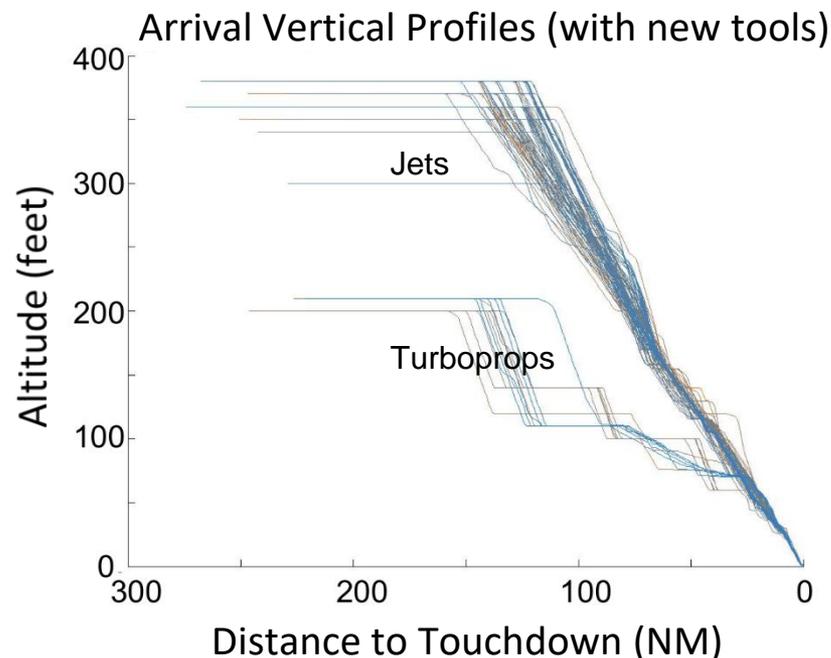
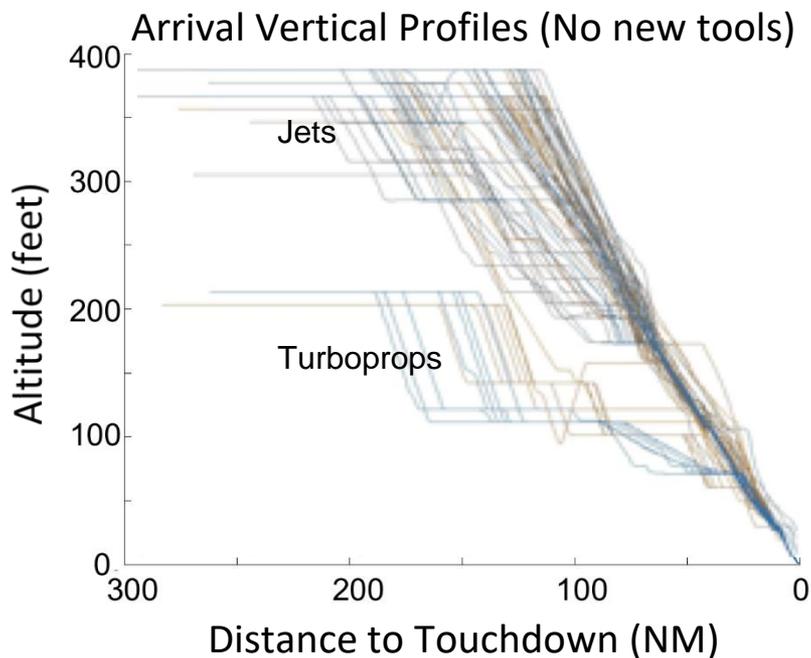
Diagram of all STARs and their IAP connections to RWYs at DEN



New Tools – An Essential Part of PBN



- Publishing new routes and operating aircraft that can tightly conform to the published routes can provide some efficiency improvements alone but including **additional tools** can further improve efficiency as demand approaches capacity

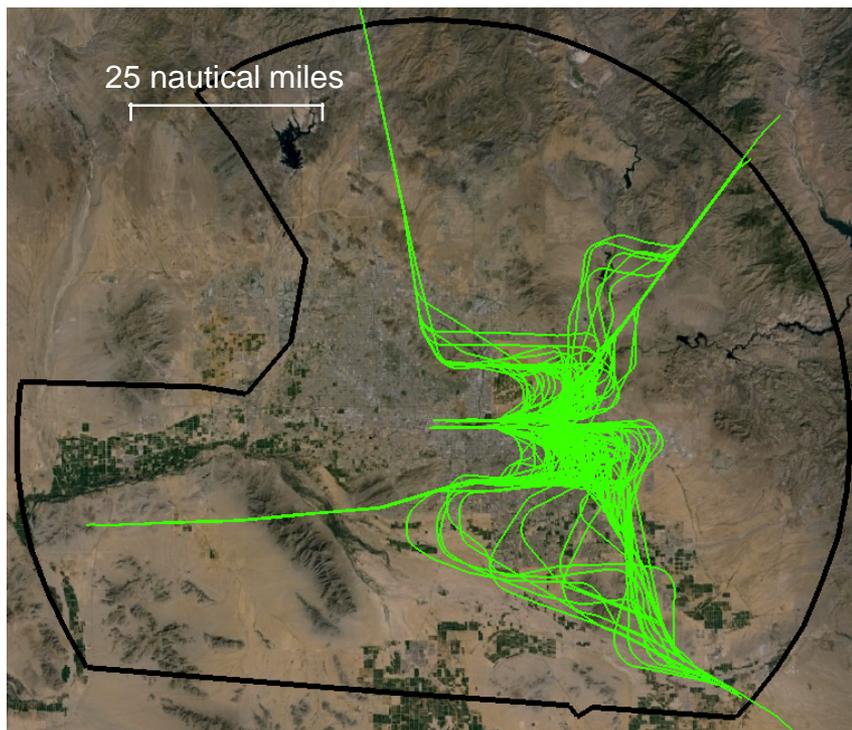




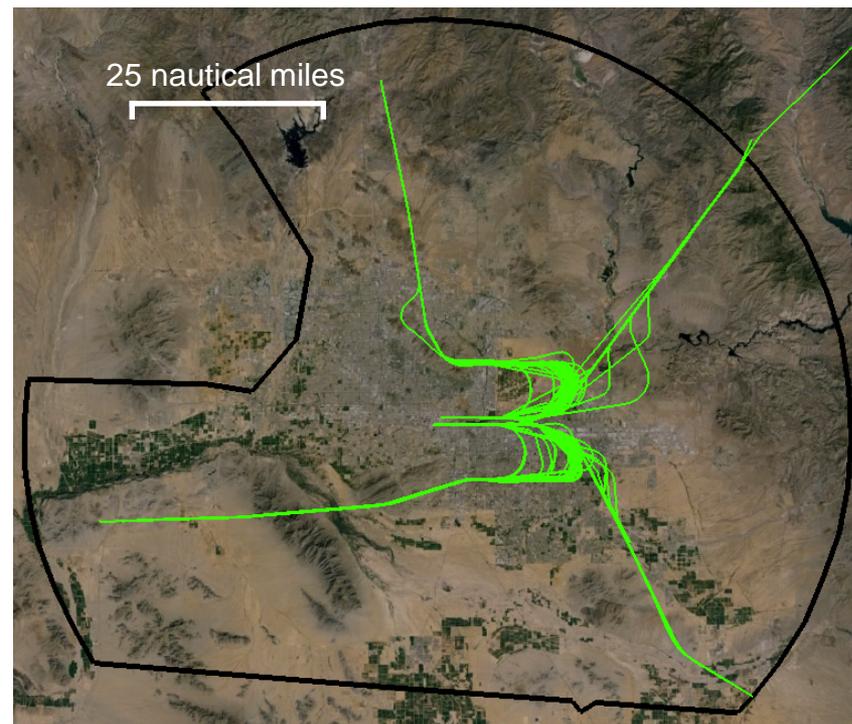
New Tools – PBN Conformance Improvement



Lateral Path Profiles



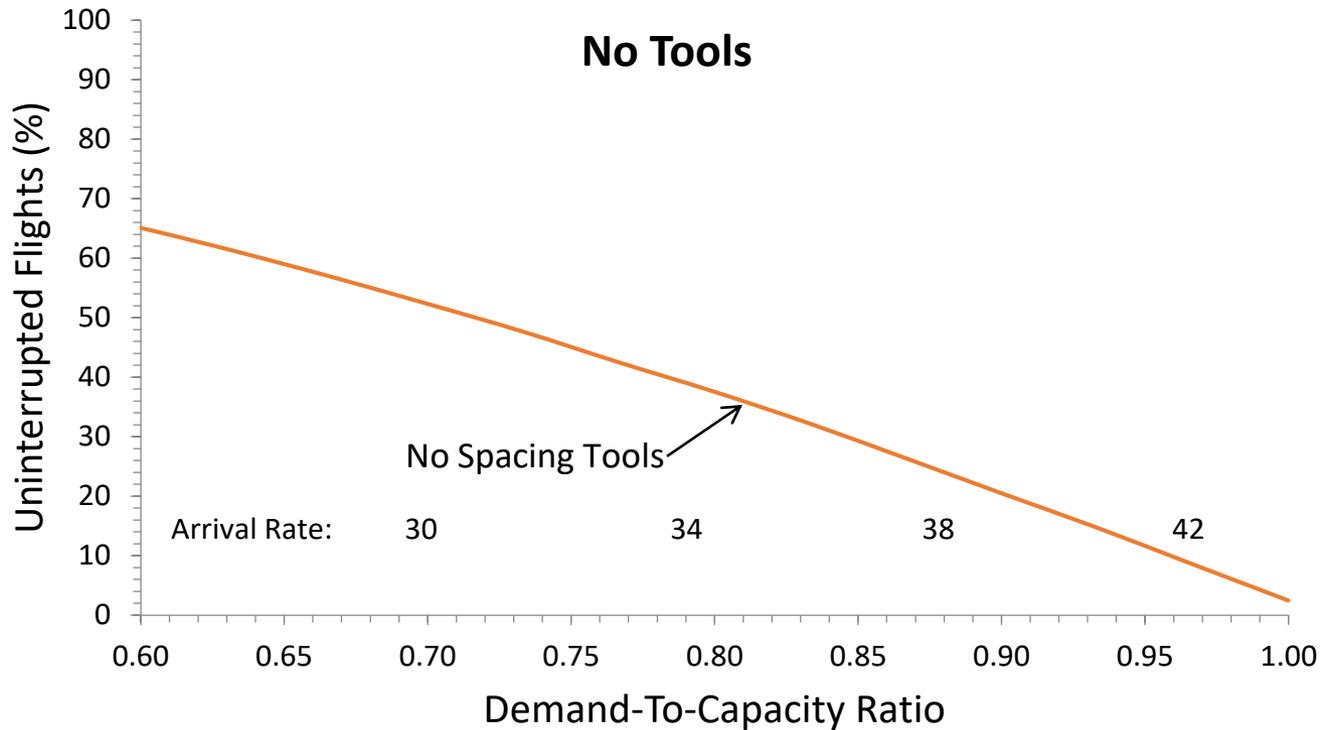
PBN routes without new scheduling tools



PBN routes with new scheduling tools



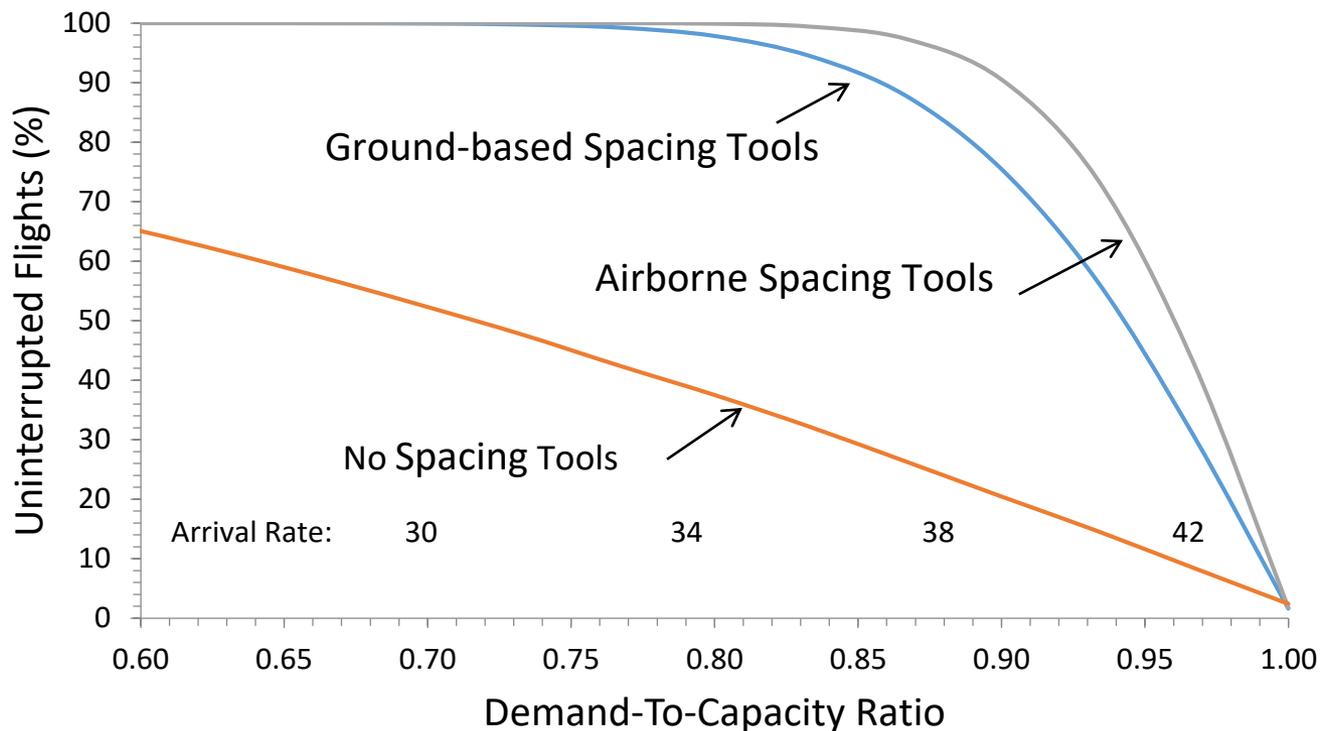
Efficiency (as Uninterrupted Flights) vs Demand-To-Capacity Ratio



Assumes Area Navigation/RNAV Optimized Profile Descents for arrival phase



Efficiency (as Uninterrupted Flights) vs Demand-To-Capacity Ratio with new Tools



Ground-based and airborne spacing tools allow more frequent use of uninterrupted RNAV OPDs for the entire arrival phase.



Summary



PBN including:

- More efficient routes
- Aircraft/equipment/crews that can conform to the routes
- Automation that supports new routes with improved scheduling and spacing tools

*Improves the operational efficiency as Demand approaches Capacity which is **critical** to enabling system wide performance and efficiency improvements at High Density Terminals*



Questions



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NASA ATD-1 Project Info
www.tinyurl.com/NASA-ATD1