William and Mary students in Math 104, *Mathematics of Powered Flight*, learn that pilots prefer to land and takeoff into the wind. If the wind is not aligned with a runway then the crosswind component of the wind is computed. The Federal Aviation Administration (FAA) provides allowable crosswind tolerances for each type of aircraft which determine the wind conditions under which an aircraft may use a runway. Deciding how to orient a new runway is typically based on wind data accumulated by the National Climatic Data Center. The FAA feeds this data into a computer program. The program determines how frequently a runway (or a combination of runways) meets the minimum crosswind tolerances for safe arrival and departure of aircraft given the history of the wind observations at that airport. Once the concrete is poured, the runways are fixed. Larger airports, such as John F. Kennedy (JFK) airport in New York, have multiple runways available.

*Figure 1: FAA airport diagram for John F. Kennedy International showing two pairs of orthogonal runways.*
Figure 1 is a diagram of the JFK airport and its runways. The available runways are 13L, 13R, 31L, 31R, 22L, 22R, 4L, and 4R (L for left and R for right). Each runway may be used for arrivals only, departures only, or mixed arrival and departure patterns. A combination of runways and their usage is called a configuration. JFK has 10 runway configurations that cover nearly all of their wind/demand patterns, e.g. [31R l 31L], [31R, 31L l 31L], [13L, 22L l 13R], etc., where l separates the arrival runway(s) from the departure runway(s) in the chosen configuration.

For the past 3 years a team of William and Mary students worked with Professor Rex Kincaid on mathematical models for making runway configuration decisions. Their work was part of a larger project funded by NASA through the Mosaic ATM company. Runway Configuration Management (RCM) decisions are complicated by a dynamic system rich with uncertainty. It is therefore not possible to deterministically forecast configurations in which to operate throughout the day. Weather conditions such as wind speed, wind direction, and cloud cover ceiling are among the most influential characteristics governing configurations available for use. Additionally, environmental constraints such as noise and no-fly restrictions over populated areas are often present at varying times of the day. Regardless of the system’s dynamic nature, the ability to generate a schedule of configuration changes is essential. RCM models are an attempt to provide air traffic controllers with a tool to assist in the scheduling of configuration changes. Figure 2 captures the interplay between RCM and other key optimization problems associated with managing the airspace and surface operations at an airport.

Professor Kincaid’s team has taken three distinct approaches to RCM problems. The first two address what is called the Strategic RCM (SRCM). The SRCM problem has a five hour planning horizon with changes to the runway configurations allowed every 15 minutes. Two optimization models were developed for SRCM. The first is a deterministic mixed integer linear program that includes marginally decreasing transition capacities associated with configuration changes. The second is a robust optimization model (ROM). ROM addresses uncertainty in the arrival demand information. The third approach narrows the time scale to 90 minutes and evaluates changes to the runway configurations every 5 minutes and is called the Tactical RCM (TRCM). The TRCM model includes individual flights rather than aggregate demand. In addition, TRCM includes airspace and surface space in decisions by considering factors such as taxi distance, fix distance, and gate assignments; the previous models were concerned solely with the available runways and their respective configurations. Finally, the TRCM model includes uncertainty in air traffic schedules and weather forecasts. A tabu search heuristic was developed to find high quality solutions to TRCM.

SciClone was the main computing resource for computing solutions to the optimization models for SRCM. The 3 years of research efforts by the William and Mary team have resulted in 7 conference presentations, 3 refereed conference proceedings publications, and 2 refereed journal articles.

**Figure 2:** Optimization problems in airport operations.


