CENTER FOR AIR TRANSPORTATION SYSTEMS RESEARCH (CATSR)

EDUCATION, ANALYSIS & RESEARCH FOR THE NEXT FRONTIER

12/2004

George Donohue, Director
Lance Sherry, Deputy-Director

School of Information Technology & Engineering
Systems Engineering & Operations Research
Objectives

• EDUCATION, ANALYSIS & RESEARCH FOR THE NEXT FRONTIER

• **Education** of the next generation of Aviation Transportation System Engineers
  – Ph.D., Masters, and Bachelors Program, Continuing Education Short Courses
  – Numerous awards at National Student Design Competitions
  – Recognized by industry as source of employees

• **Applied Research and Knowledge Transfer**
  • Analysis and Simulation of complex, stochastic, distributed, network systems for the world-wide air transportation systems:
    – Congestion Management/Slot Auctions
    – Airport Capacity
    – Airspace Optimization
    – NAS Network System Performance
    – Network System Safety
    – Human Factors
    – Complex System Development Estimation and Management
    – Unmanned Air Vehicles

• **Basic Research**
  – Analysis, simulation of complex, stochastic network systems
  – Interaction between economic, safety, performance objective functions to operate network at optima
  – N-sided game theory with experimental auctions and stochastic agent-based simulations
Research Sponsors

- Member of the FAA National Center of Excellence in Operations Research (NEXTOR)
  - University of Maryland
  - MIT
  - University of California – Berkley
  - Virginia Tech

- Sponsors
  - NASA, FAA, National Science Foundation

- Industry Collaborators/Partners:
  - Boeing - ATM
  - GRA
  - Honeywell
  - LMI
  - Metron Aviation
  - Boeing - Preston Aviation
  - RAND Corporation
  - Raytheon
  - Seagull Technologies
  - Sensis
  - TRIOS
  - EuroControl
  - Airport Authorities
  - Airlines
Organization

Board of Directors:
Director: Dr. George Donohue
Deputy Director: Dr. Lance Sherry

Director:
Dr. George Donohue

School of Information Technology & Engineering:
Dean: Lloyd Griffiths

System Engineering & Operations Research Department:
Chair: Ariela Sofer

GMU Office of Sponsored Programs
Director: Ann McGuigan

Complex Network Control through Economic System Engineering
Dr. G. Donohue
Dr. K. Hoffman

Proposals, Contracts, and Program Management

Airspace & Airport Modeling and Simulation/
Stochastic Simulation
Dr. A. Klein
Dr. C.H. Chen
Dr. G. Donohue

Quantitative Assessment of Network System Safety
Dr. John Shortle
Dr. Don Gross
Dr. Brian Mark

Cognitive Engineering & Human Factors
Dr. L. Sherry

L. Le
P. Railsback

A. Yousefi
N. Xi
D. He
D. Wang

B. Jeddi
Y. Xie
B. Mezhepoglu
Complex Network Control through Economic Systems Engineering

• Large, complex networks provide critical infrastructure to nation
  – public-private owned
  – stochastic behavior
  – Significant contributors to economy, large security implications
  – Major capital investment with long breakeven periods (+/- 20 years)

• Examples:
  – Air Transportation
  – Power-grid
  – Petrochemical pipelines
  – Groundwater (fresh and waste)
  – Wireless communications (spectrum, infrastructure)

• Networks characterized by “contradictions” in the objective functions between
  – operators of infrastructure (e.g. Air Traffic Control, airports)
  – operators of service (e.g. airlines, aircraft manufacturers)

• Interdisciplinary research on interaction of conflicting economic objective functions to maximize network system performance
  – Analysis & Simulation (adaptive stochastic agents)
  – Economic n-sided game theory with experimental auctions and stochastic agent-based computer simulation
Congestion Management/Slot Auctions

- Develop a practical proposal for using slot auctions at U.S. airports
- Emphasis for auction design that could be used at New York’s LaGuardia Airport
- Research examines:
  - likely impact of alternative allocation mechanisms have on private and public organizations
  - how changes impact FAA, airline and airport operations.
- Collaborators:
  - University of Maryland
  - MIT
  - University of California, Berkeley
  - Harvard University
  - Gellman Research Associates

Simulation of Complex System with “Conflicting” Objective Functions

Strategy Simulator
Ventana Systems www.vensim.com

NAS Strategy Simulator: Sectors & Flows

Pax & Cargo
- Baseline Demand
- Effective Price
- Trip Time
- Market Clearing
- Effect on GDP

Fleets & Schedule
- Passenger & Flight Delays
- Flight Cancellations
- Schedules
- Fleet Finances
- Aircraft Fleets

capacity offered

services offered

taxes

NAS
- Airport Capacity
- Enroute Capacity
- ATC Infrastructure
- ATC Controllers
- FAA Budgets
- Aviation Trust Fund

JPDO

Equipage
Airspace and Airport Modeling & Simulation/
Stochastic Simulation and Modeling

- Analysis of operation of NAS, ATC, Airports
  - stochastic behavior of components and overall complexity
  - analysis, predictions conducted through simulation
- Expertise in set-up and operation of industry simulation tools
  - TAAM
  - GMU Stochastic Network Sim Model
  - DPAT
  - ACES
  - RAM

- Research:
  - Airspace Optimization
  - Airport Capacity (including hub network analysis)
  - Developing next generation of computer simulation methods for hybrid
    simulation/analytic queueing model
  - Analyze NAS data (e.g. ETMS, Severe Weather) for space-time correlations
    between variables (e.g. utilization, capacity, delays, …)
Airport & Airspace Modeling

30% Delay reduction
Saving 1.5 min per aircraft

Courtesy: Preston Group, Boeing
Airspace & Airport Modeling

• What Research & Analysis has been done:
  – Evaluate effect of proposed runway or taxiway maintenance works on the airport flight schedule and operations
  – Assess benefits of investments in new terminals, additional gates, taxiways or runways, and identify best design solutions
  – Evaluate airport preparations for airline fleet changes, traffic growth, changes in procedures and regulations (e.g. noise abatement, de-icing)
  – Airline simulation of entire schedule (worldwide if needed), including all other traffic at its hubs, secondary airports, or airspace sectors of interest
  – Airline planning operations, fleet changes, aircraft substitutions
  – ATO simulate the entire of air traffic for any region in a given country (national, oceanic)
  – Assess the traffic complexity and controller workload vs. airspace efficiency, initiate airspace redesign where required, evaluate its environmental impact
  – Prepare for airline fleet changes including regional jets and new large aircraft; traffic growth projections; changes in procedures and regulations;
  – Assist in the introduction of new CNS/ATM technologies and ensuing changes in airspace operation
Passenger Simulations

Courtesy: Preston Group, Boeing
Chicago O’Hare Average of sum of the arrival delays in 15 minute time-blocks – (0:00 – 24:00)
Prepared by; Danyi Wang (Wang, Donohue, 2004)
Stochastic Model of NAS - Bayesian Networks

Bayesian Network derived from Arrival/Departure Data from KORD
Prepared by: Ning Xi, Dr. Chen (2004)
Airspace Optimization

- The FAA performs Air Traffic Flow Management & Control in the En-route Airspace
  - 20 ATC Centers
  - strategically located
- Locations and airspace sectors established in the 1960's
- Current Airspace Structure is inefficient in dealing with peak flows and irregular operations
  - evolution of route structures
  - nature of disruptions on air traffic flow due to weather
  - capacity limits of airports
  - advances in technology
- Proposed concept is to reduce the ATC Centers from 20 to significantly fewer (e.g. 6)
  - develop the requirements to re-map airspace

ATC controller workload for current route structure
Prepared by: Arash Yousefi (Yousefi, Donohue, 2004)
Quantitative Assessment of Network System Safety

- Network safety is determined by stochastic processes (not probabilistic)
- As network approaches capacity limits, safety and capacity must be traded-off
- Application of advanced Probabilistic Safety Assessments methods to estimate safety of stochastic air transportation network
- Analysis of relationship between safety and capacity

Arrival time distribution at Atlanta Runway 27 (357 observations, VMC)
Simultaneous Runway Occupancy (SRO)

- Stochastic model of arrival flows to independent runway
- Heterogeneous fleet mix
- Probability of SRO:
  - Mean Runway Occupancy Time (ROT)
  - Std. Dev. ROT
- Variance significant factor in SRO

Prepared by: Richard Xie (Xie, Shortle, 2004)
Wake Vortex Separation Distance


NLR – WAVIR Tool for Stochastic Simulation of Wake Vortex Separation Distances (Speijker, 2003)
## INCREASING SAFETY
Light crosswind of **1.8 knots** and no head- or tailwind

<table>
<thead>
<tr>
<th>Lead Follow</th>
<th>Large Jumbo Jet Actual (ICAO Std.)</th>
<th>Medium Jet Actual (ICAO Std.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Jumbo Jet</td>
<td>4.25 nm (4.0nm)</td>
<td>2.5nm (3.0nm)</td>
</tr>
<tr>
<td>Medium Jet</td>
<td>6.5nm (5.0nm)</td>
<td>2.5nm (3.0nm)</td>
</tr>
<tr>
<td>Regional Jet</td>
<td>5.0nm (5.0nm)</td>
<td>3.25nm (3.0nm)</td>
</tr>
<tr>
<td>Light Turbo prop</td>
<td>6.5nm (6.0nm)</td>
<td>3.5nm (5.0nm)</td>
</tr>
</tbody>
</table>

## INCREASING CAPACITY
Safe separation distance for a crosswind **3.7 knots** and no head- or tailwind.

<table>
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</table>
Cockpit Display of Wake Vortex Separation

- Create situation awareness for pilots
- Closely Spaced Parallel approaches (< 2500’)
  - Lateral traffic separation
  - Longitudinal station keeping
  - Wake prediction
  - Wake display
  - Guidance
  - Avoidance maneuvers
Cognitive Engineering & Human Factors

• **Background:**
  – The overall safety and efficiency of the aviation system is largely dependent on human operators
  – Design, Analysis and Testing of proposed changes must evaluate performance of system including the operators

• **Research:**
  Stochastic models of Air Traffic Controllers and Pilots
  – Blom (Stochastic Human-in-the-loop Models) & Corker (AirMidas)
  Human Factors in FAA Certification Process
  – Human Factors Certification Plan
  – Human Factors/Usability Analysis
Faculty, Researchers, & Staff

- Dr. George Donohue  (gdonohue@gmu.edu)
  - Ph.D. Mechanical and Aerospace Engineering, Oklahoma State University (1972)
    - Professor, System Engineering & Operations Research, GMU
    - Director, Center for Air Transportation Systems Research
    - Associate Administrator of the FAA (Research, Engineering and Acquisitions)
    - Vice President, RAND Corp.
    - Director Aerospace Technology Office, Defense Advanced Research Projects Agency (DARPA)

- Dr. Lance Sherry  (lsherry@gmu.edu)
    - RAND – Science & Technology
    - Honeywell Air Transport Systems (Flight Test, Systems Engineer, Program Manager, R&D & Strategic Planning)

- Dr. Alexander (Sasha) Klein  (aklein1@gmu.edu)
    - Senior V.P. Preston Group/Boeing. Principal designer of TAAM air traffic simulation model

- Dr. Don Gross  (dgross1@gmu.edu)
  - Ph.D. Cornell University (1961)
    - Professor; Applied Probability, Queueing Theory, Queueing and Simulation

- Dr. C.H. Chen  (cchen9@gmu.edu)
  - Ph.D. Harvard University - Division of Applied Sciences (1994)
    - Associate Professor of Systems Engineering & Operations Research, GMU
    - Acting Chairman, Graduate Group of Systems Engineering, Univ. of Pennsylvania.
    - Assistant Professor of Systems Engineering, Univ. of Pennsylvania

- Dr. John Shortle  (jshortle@gmu.edu)
    - Assistant Professor, Dept. of Systems Engineering & Operations Research, GMU
    - Mathematical and Statistical Modeling, U S WEST Advanced Technologies.

- Dr. Karla Hoffman  (khoffman@gmu.edu)
  - Ph.D. George Washington University (1975)
Facilities

State-of-the-art Lab with Simulation & Analysis Tools

800 sq. ft lab space + offices

Move into new R&D building 2006

Tools:
- TAAM
- MatLab
- Arena
- SAS
- Oracle
- Flight Explorer
- Access to ETMS
- Home-brewed Tools
Member NEXTOR - FAA Center of Excellence

- Federal Aviation Administration (FAA) National Center of Excellence for Aviation Operations Research (NEXTOR)
- Member Universities
  - The University of Maryland
  - The Massachusetts Institute of Technology
  - The University of California, Berkeley
  - The Virginia Polytechnic Institute and State University.
  - George Mason University
- NEXTOR Research Projects
  - IDIQ Contracts
  - Grants
- NEXTOR Program Manager: Scott Simcox  510-643-5635
Contact Info

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Directions

DIRECTIONS TO FAIRFAX CAMPUS FROM THE CAPITAL BELTWAY (I-495)
Take exit 54, Braddock Road (Route 620), and take the westbound fork. Follow Braddock Road West for approximately six miles.* Pass the first entrance to the university and turn right at the stop light at Roanoke River Road. Bear right at the fork in the road. Take your first left onto Mason Pond Drive; parking is available in the Parking Deck, the last building on the right. An information kiosk is located outside the third level of the deck to help you navigate the campus.

*Alternate 1: Take a right on Nottoway Lane; Left on Patriot Circle; Right on Mason Pond Drive to the Parking Deck. Alternate 2: Take a right on Roberts Road; Left on Shenandoah; Left on Patriot Circle; Right on Mason Pond Drive to the Parking Deck.

DIRECTIONS TO FAIRFAX CAMPUS VIA I-66E FROM FRONT ROYAL & FAIRFAX COUNTY PKWY
Exit at the Fairfax County Parkway South (Route 7100). Exit the Parkway at Braddock Road, and turn left onto Braddock Road. Take the first left past Route 123 (Ox Road) onto Roanoke River Road.* Bear right at the fork in the road. Take the first left on Mason Pond Drive to the Parking Deck, the last building on your right. An information kiosk is located outside the third level of the deck to help navigate the campus.

*Alternate: Take the second left past Route 123 (Ox Road) onto Nottoway Lane; Take a left on Patriot Circle; Right on Mason Pond Drive to the Parking Deck.

http://www.gmu.edu/welcome/Directions-to-GMU.html#495