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

GMU Office of Sponsored Programs
Director: Ann McGuigan

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

Complex Network Control through Economic System Engineering
Dr. G. Donohue
Dr. K. Hoffman
L. Le
P. Railsback

Airspace & Airport Modeling and Simulation/
Stochastic Simulation

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

System Engineering & Operations Research Department:
Chair: Ariela Sofer

School of Information Technology & Engineering:
Dean: Lloyd Griffiths

GMU Office of Sponsored Programs Director: Ann McGuigan

B. Jeddi
Y. Xie

Cognitive Engineering & Human Factors
Dr. L. Sherry

B. Mezhepoglu

Proposals, Contracts, and Program Management

Gain spectrum for the above figure.
Complex Network Control through Economic Systems Engineering

• **Background:**
  - Large, complex, public-private owned, stochastic, network systems provide critical infrastructure to nation
    • 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

• **Research Projects:**
  – Congestion Management/Slot Auctions (FAA, NSF)
Example Project: 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

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

- money paid

- trips taken

NAS

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

JPDO

- Equipage

Strategic Simulator
Ventana Systems www.vensim.com
Airspace and Airport Modeling & Simulation/
Stochastic Simulation and Modeling

• **Background:**
  – 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

• **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
NAS Performance Metrics

Chicago O’Hare Average of sum of the arrival delays in 15 minute time-blocks – (0:00 – 24:00)
Prepared by; Danyi Wang
Example Project: 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
Quantitative Assessment of Network System Safety

- **Background:**
  - Network safety is largely a result of stochastic processes
  - As system approached 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

- **Research:**
  - Conduct safety analysis for FAA and NASA
    - Reduced Wake Vortex Separation for IFR Arrivals and Departures
    - Arrival/Departures into proposed Self Controlled Airspace at non-towered airports

Arrival time distribution at Atlanta Runway 27 (357 observations, VMC)
Prepared by: C. Haynie
Example Project:
Wake Vortex Separation Distance Evaluation

Distribution of Lateral Position

Distribution of Vertical Position

Lead Aircraft

Follow Aircraft

Distribution of Vertical & Lateral Position and Strength of Wake Vortex with Strength > X from Lead Aircraft

Distribution of Longitudinal Position (= Inter-arrival distribution)
Example Project:
Wake Vortex Separation Distance Evaluation

Probability of Follow Aircraft *Encounter* with Wake Vortex > Strength X from Lead Aircraft = \( f (\)  
- Arrival Separation Distance Standard for Lead/Follow
- Distribution of Vertical Position of Lead Aircraft
- Distribution of Lateral Position of Lead Aircraft
- Distribution of Vertical Position of Follow Aircraft
- Distribution of Lateral Position of Follow Aircraft
- Distribution of Longitudinal Position of Follow Aircraft
- Distribution of Lateral Position/Vertical Position/Strength of Wake Vortex from Lead Aircraft
- Distribution of Eddy Dissipation rate and Cross Wind, Tail Wind)

Probability of Follow Aircraft Incident/Accident with Wake Vortex > Strength X from Lead Aircraft = \( f (\)  
- Above P()
- Distribution of Pilot/Autopilot Response
- Aerodynamics of Follow Aircraft
- Height Above Ground

Set Wake Vortex Separation Distance, for different procedures, to satisfy safety criteria
Example Project: Wake Vortex Separation Distance Evaluation

NLR Wake Vortex Separation Distance Model

Multi-lateration PDF’s

FLIGHT PATH

WEATHER

VORTICES

Simulated/Measured positions and strength

VORTEX SEVERITY

Encounter severity classification

ENCOUNTER

Simulated/Measured positions and strength

AERODYNAMICS

PILOT RESPONSE

5 A/C classes

Instantaneous Risk

Accident risk
Example Project: 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

- 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
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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