State of the National Airspace Infrastructure

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Why Do We Need Reliable and Modern Aviation Infrastructure?

- The United States accounts for approximately 30 percent of all commercial aviation and 50 percent of all general aviation activity in the world.
- Prior to September 11, 2001 the NAS handled 1.9 million passengers traveling on 60,000 flights daily.
- NAS moves over 600 million passengers per year. Projected enplanements in year 2013 is over 900 million.
- NAS conducts over 26 million operations per year. Projected number of operations in 2013 is over 33 million.

Source: ACE 2002
Background

- 546 commercial service airports:
  - 422 have more than 10,000 enplanements and are classified as primary airports (Commercial service airports are defined as public airports receiving scheduled passenger service and having 2,500 or more enplaned passengers per year).
- 31 large hub airports account for 70 percent of all passenger enplanements.
- 37 medium hub airports account for 19 percent of all enplanements
- 74 small hub airports account for 8 percent of all enplanements

Source: NPIAS

50 airlines
Number of Airports by Ownership and Use (January 2001)

19,306
Total U.S. Airports

5,314
Open to Public

13,992
Closed to Public

4,160
Public Owned

1,154
Private Owned

3,489
NPIAS Airports

3,364 Existing
3,226 Public Owned
138 Private Owned

125 Proposed

122 Primary
124 Commercial Service
260 Reliever
2,558 General Aviation

0 Primary
5 Commercial Service
9 Reliever
111 General Aviation

Source: NPIAS
## Background

### New Runways in OEP

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<tr>
<th>Airport</th>
<th>Runway</th>
<th>FY Runway to Open</th>
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<td>Seattle (SEA)</td>
<td>16W/34W</td>
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</table>

Source: OEP
Background

NAS Inventory

• NAS has about 44,000 pieces of equipment and services that provide air traffic management (ATM) services.

• NAS’ large inventory of capital assets are in various stages of approaching physical or technical obsolescence.

Source: http://www.faa.gov/ats/aaf/
Background

 Frequencies of Scheduled (Cause Code 60) and Unscheduled Outages (Cause Code 80) for Airport Surveillance Radars (ASR)

Source: NAPRS data
Background

Frequency of Scheduled (Cause Code 60) and Unscheduled Outages (Cause Code 80) for Localizers (LOC)

Source: NAPRS data
Background

Downtimes of Scheduled (Cause Code 60) and Unscheduled Outages (Cause Code 80) for Localizers (LOC)

Source: NAPRS data
Background

Frequency of Scheduled (Cause Code 60) and Unscheduled Outages (Cause Code 80) for All NAPRS Equipment

Source: NAPRS data

Frequency of Scheduled (Cause Code 60) and Unscheduled Outages (Cause Code 80) for All NAPRS Equipment

Source: NAPRS data
Background

Downtimes of Scheduled (Cause Code 60) and Unscheduled Outages (Cause Code 80) for All NAPRS Equipment

Source: NAPRS data
Background

NAS Inventory

- ~ 500 FAA Managed Air Traffic Control Towers
- ~ 180 Terminal Radar Control Centers (TRACONs)
- > 730 Sectors
- ~ 60 Flight Service Stations
Background

NAS Inventory

• 20,000 – 25,000 administrative and mission support computers

• 1,800 people to maintain and operate NAS software

• $100 million contract costs to maintain NAS software
NAS building and building systems infrastructure is made up of:

- 21 Air Route Traffic Control Centers (ARTCCs)
- 3 Center Approach Control (CERAPs)
- 1 Combined facility (ATC/TRACON/CERAP)
- 519 Terminal facilities
- 3 Automated Flight Services Stations (Alaska)
- 14 Flight Service Stations (Alaska)
- 9,000 General National Airspace unstaffed facilities

Power systems

- 3800 engine generators
- 587 uninterruptible supply systems
- 77,000 batteries
Division of the NAS into 9 different regions
## List of Facilities, Split on the Basis of Type and Region

<table>
<thead>
<tr>
<th>Type of Facility</th>
<th>Facilities Reported by Region</th>
<th>TOTAL</th>
<th>AAL</th>
<th>ACE</th>
<th>AEA</th>
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NAS Regions

- Each of 9 regions signifies different climactic conditions.
- Adverse weather conditions vary a lot over the 9 different regions, including the large temperature changes in the Alaska region and strong winds in southern region.
- Varied weather patterns result in different deterioration patterns among same types of facilities.
- Conditions of the facilities vary.
Facility Assessments

Facility Condition Index (FCI)

\[ FCI = \text{Dollar value of backlog (Maintenance & repair)} \]
\[ \quad \text{Current replacement value} \]
There are about 800 facilities (ATCTs, ARTCCs, or TRACONs) in the NAS, with the average age between 16 and 40 years. For example, average ages of specific facilities and equipment types are:

<table>
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<th>Facility</th>
<th>Average Age (Years)</th>
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<td>Primary terminal radars</td>
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</table>
The maintenance of individual equipment or systems supporting air traffic control of the NAS requires technicians trained in many disciplines deployed over the entire country.

Maintenance workforce is managed out of a national network of cost centers.

Each cost center has a limited number of technicians who are responsible for providing scheduled and unscheduled maintenance and repair for the equipment assigned to that center.
Background

NAS Infrastructure Management

• Different types of equipment have different repair time characteristics.

• Technicians are trained to repair specific types of equipment.

• To date there is no centralized system for equipment maintenance.
Does Periodic Maintenance Cause Unscheduled Outages?

An Investigation of the National Airspace System Equipment Outages

Motivation

More unscheduled outages during day

- Why?
- Hypothesis:

  Scheduled maintenance linked to outages
  “Maintenance-induced-maintenance”
Note: Eastern Region includes: New York, New Jersey, Pennsylvania, West Virginia, Virginia, Maryland, Delaware, and DC
Methods

Data from Maintenance Management System

Unscheduled outages from:

1. Equipment failure or malfunction
2. Unknown cause

Find time between each PM and next outage on given equipment
Findings

- Correlation coefficient of 0.73 between PMs and outages
- Mean time between PM and outage is 840 hrs.
- If outage is “caused” by PM, would expect to see it in first few hours after PM
- If outages are random, would expect 17 outages in the first hour
Findings

Number of Unscheduled Equipment Outages Occurring after Periodic Maintenance

All Regions, 1/1/2004-12/31/2004

Counts of Unscheduled Equipment Outages

Hours after Completion of PM Activity
Findings—Time of Day

Counts of Outages and PM's vs. Time of Day

*Eastern Region, 1/1/2000-12/31/2004*

- **Count of Unscheduled Outages Occurring within 1 hr. after Completion of a PM**
- **Number of PM's**
Findings—Day of Week

Counts of PM's and Outages Occurring within 1 hr. after a PM by Day of Week

All Regions, 1/1/2004-12/31/2004

Sunday | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday

Count of Unscheduled Outages Occurring within 1 hr. after Completion of a PM

Number of PM's
Periodic Maintenance and Unscheduled Outages

- Maintenance-induced maintenance or secondary maintenance occurs, which is also common in industrial facilities.

- PM’s should be performed during time periods when the consequence of an outage is low, i.e., when there are low numbers of air traffic controllers, pilots, and aircraft relying on the equipment.

- The fact that some PM’s do cause unscheduled outages does not mean, however, that reducing the number of PM’s will necessarily decrease the number of unscheduled outages.
Future Work

- Differences across equipment types/locations
- Delay-causing outages
  - Outages “of consequence”
- Balance between too many PMs and too few
Facility Assessments

Facility Condition Index (FCI)

$$FCI = \frac{\text{Dollar value of backlog (Maintenance & repair)}}{\text{Current replacement value}}$$
Surveillance
Communications
Shelter Replacement
Structural Towers
Access Roads
Roofing
NAS Power Systems have Multiple Components

- **UPS**
  - Service Life - 10 Years

- **Grounding**
  - Service Life - 20 Years

- **Lightning Protection**
  - Service Life - 20 Years

- **Cable Distribution**
  - Service Life - 20 Years

- **Transformer**
  - Service Life - 20 Years

- **Switchboard**
  - Service Life - 20 Years

- **Engine Generator**
  - Service Life - 20 Years
Critical Power Distribution System (CPDS) Have Multiple Complex Subsystems
Both GNAS and ARTCC Batteries Must Be Replaced before They Fail

GNAS Battery Bank
“Wet Cells”

ARTCC UPS Batteries
“VRLA Cells”
DC Systems Replace Standby Generators

Before  

After
Legacy Engine Generators: Overdue To Be Replaced

Current engine generator
Airport Buried Power Cable: Failure Causes Delays

Philadelphia Airport Power and Data Cable Outage, July 2005
Proper Grounding Is Critical

-Phoenix TDWR TVSS

-Chicago ATCT UPS

Lightning seeks elevated objects such as ATCTs, Radars, Antennas, fences
Commercial and Standby power outages are increasing.
Summary

- Infrastructure is critical to running the NAS
- Infrastructure does not get a lot of publicity
- Introduce maintenance optimization models that also consider the airport/airline side of the problem
- Introduce reliability-centered maintenance.

Cost Center Description:
- Staffing
- Sparring
- Probability distributions for equipment MTBF
- Type of failure
- Scheduled or unscheduled
- Travel Time
- Shift Policies
- Administrative Time
- Technician Qualifications

Service Description:
- Equipment making up a service
- Redundancy

Cost Center

Module

Output Measures:
- Technician Utilization
- Outage Durations

Service Availability Module

Output measure:
- Availability

Airport Model

Airport Characteristics:
- Aircraft mix
- Aircraft class
- Speed
- % weather (VFR and IFR)
- Final Approach Path Geometry
- Holding Pattern
- Number of runways
- Aircraft arrival demand
- Sequencing rule
- Mile-in-trail separation matrices
- Runway occupancy time

Output Measures:
- Capacity
- Aircraft delay
- Runway utilization
- Final approach path statistics
- Aircraft queue statistics