

# **Multi-biometric Fusion – From Research to Operations**

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**Lawrence D. Nadel, Ph.D.**

**Harold J. Korves**

**Bradford T. Ulery**

**Denise Masi, Ph.D.**

# Agenda

- **Biometric Systems Engineering Challenges**
- **Multi-biometric Fusion**
  - Overview
  - Large-scale system example
  - Research findings (NIST BSSR1 data)
- **Multi-biometric System Engineering**
  - Watch list example – impact on system users
- **Integrated Multi-biometric Accuracy and Network Queuing Model**

# Some of the Challenges to Engineering Large-Scale Identification Systems

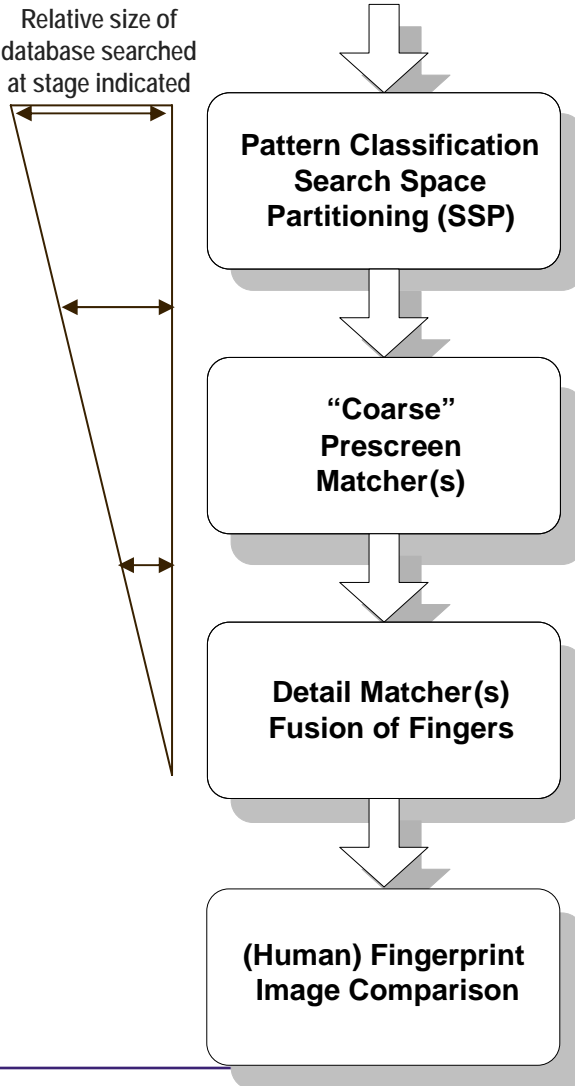
- Accuracy (FAR, TAR)
  - Speed (data acquisition & processing times; throughput)
  - Population characteristics (size, age, presentation, cooperativeness, operational familiarity)
  - System integration (manual processes; human factors – FTE/FTA, data quality)
  - Access point vs. surveillance operation
  - Vulnerability to fraud and spoofing – countermeasures
  - Public perceptions (acceptance)
  - System life expectancy (biometric template aging)
  - Cost-benefit tradeoff analyses (acquisition, operation, maintenance)
- ... along with varying environmental and threat conditions

# Multi-biometric Fusion

- **Biometric fusion combines biometric characteristics derived from**
  - One or more modalities or technologies (algorithms, sensors)
  - Multiple characteristics derived from samples
  - Multiple or repeated biometric instances
- **Goal – identify or authenticate individuals more *effectively* than when using a single matcher and/or sample**
- **Benefits**
  - Improve accuracy
  - Improve system robustness and fault tolerance
  - Improve efficiency
- **Greatest benefits are derived when integrating uncorrelated biometric characteristics**

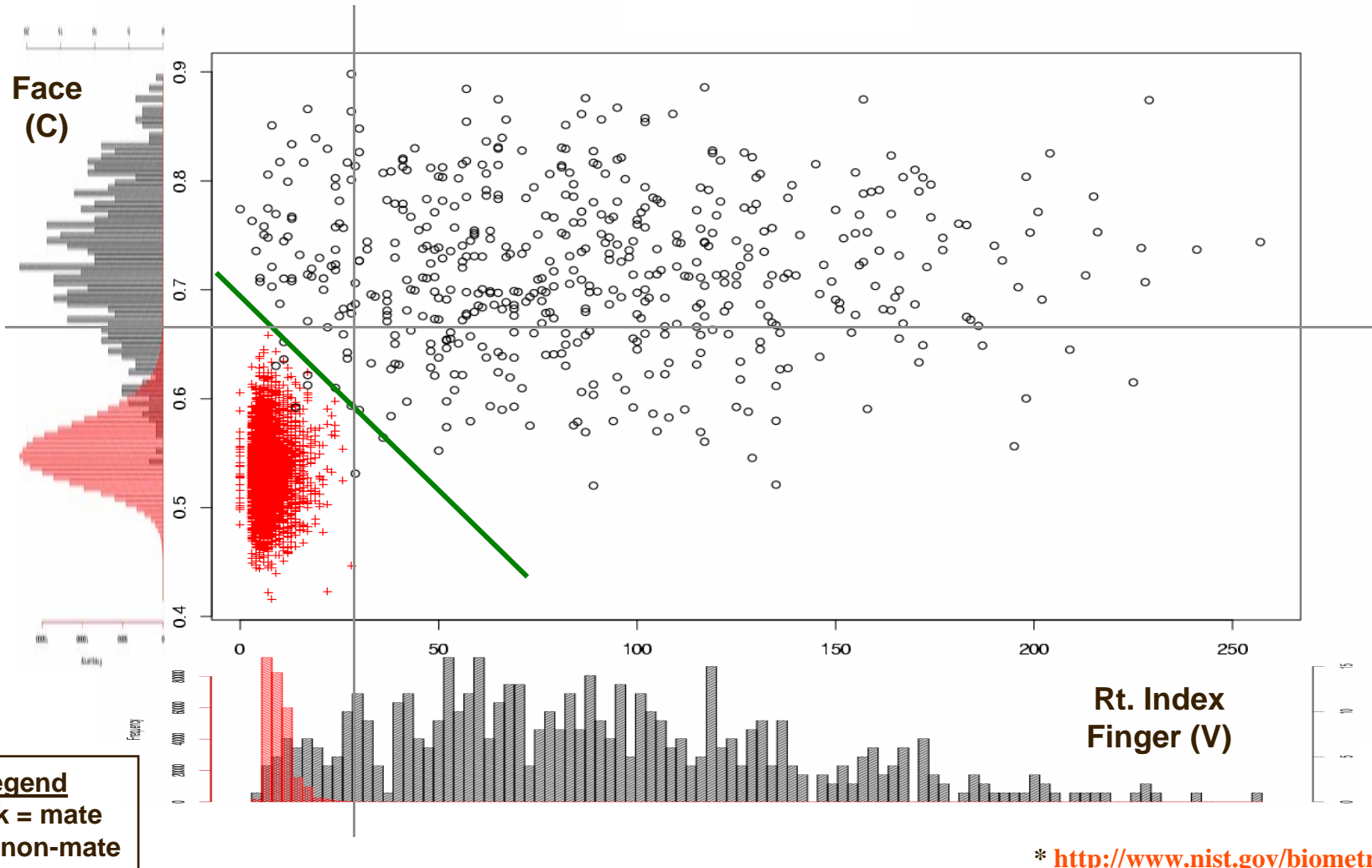
# Example of Large-Scale Biometric Fusion – FBI IAFIS

Relative size of database searched at stage indicated

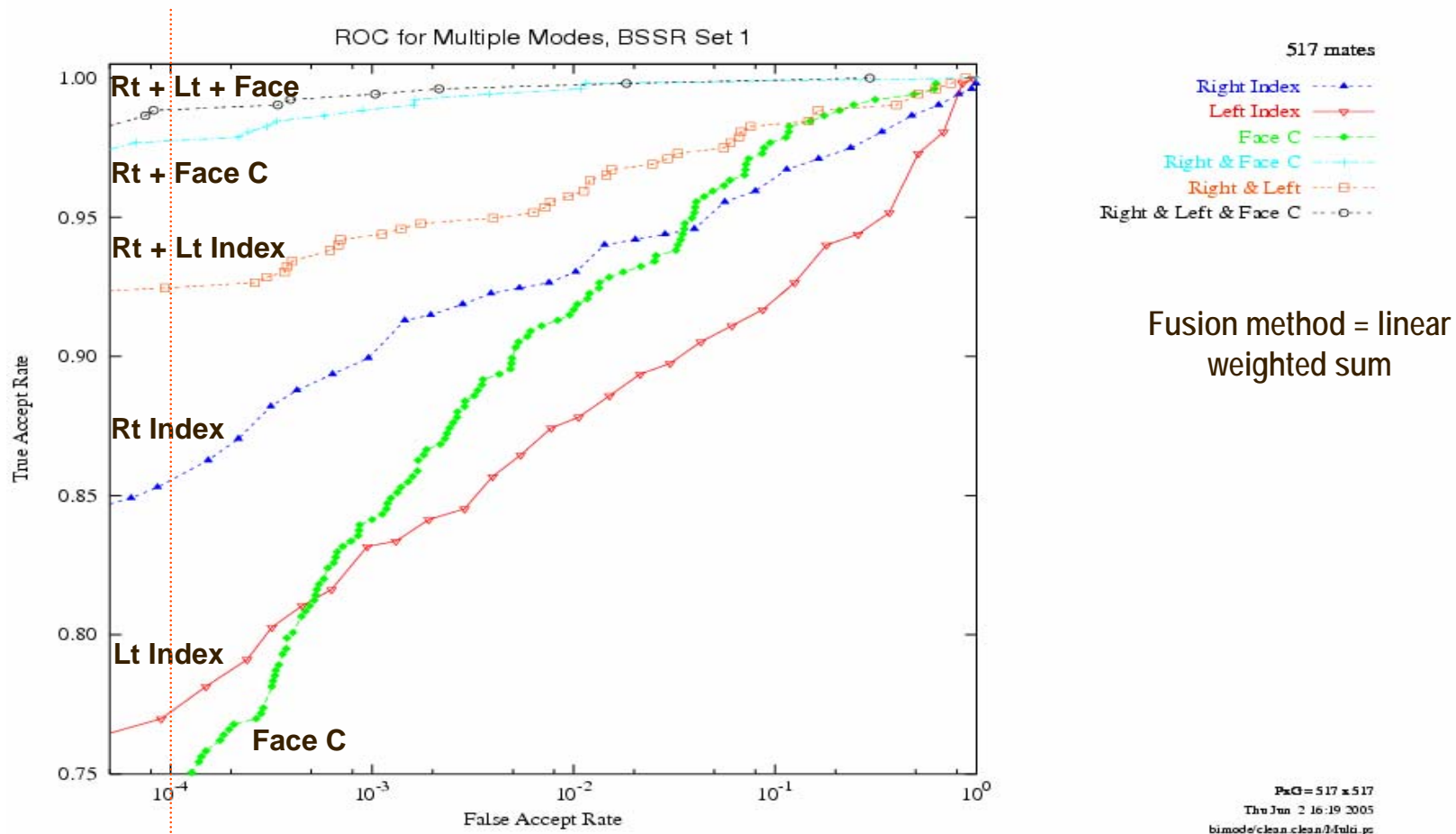


- **FBI Integrated Automated Fingerprint Identification System (IAFIS)**
  - 48 million tenprints in Criminal Master File (CMF) database
  - Ten-print searches – 40,000 to 100,000 daily
  - Operational response times (including time for human expert verification)
    - Less than 2 hours for criminal electronic submissions
    - Less than 24 hours for civil electronic submissions
- **IAFIS biometric fusion**
  - Single modality – fingerprint
  - Multi-instance fusion – ten fingers
  - Multi-algorithm fusion
    - Search space partitioning – pattern classification
    - Pre-screen – “coarse” matcher, many candidates, high search throughput
    - “Fine” matcher, few candidates, low search throughput
      - Generally, two fingers used; up to ten if necessary
- **IAFIS is extremely accurate**

# Visual Analysis of Multi-biometric Score Data (NIST BSSR1 Face and Finger Data\*)

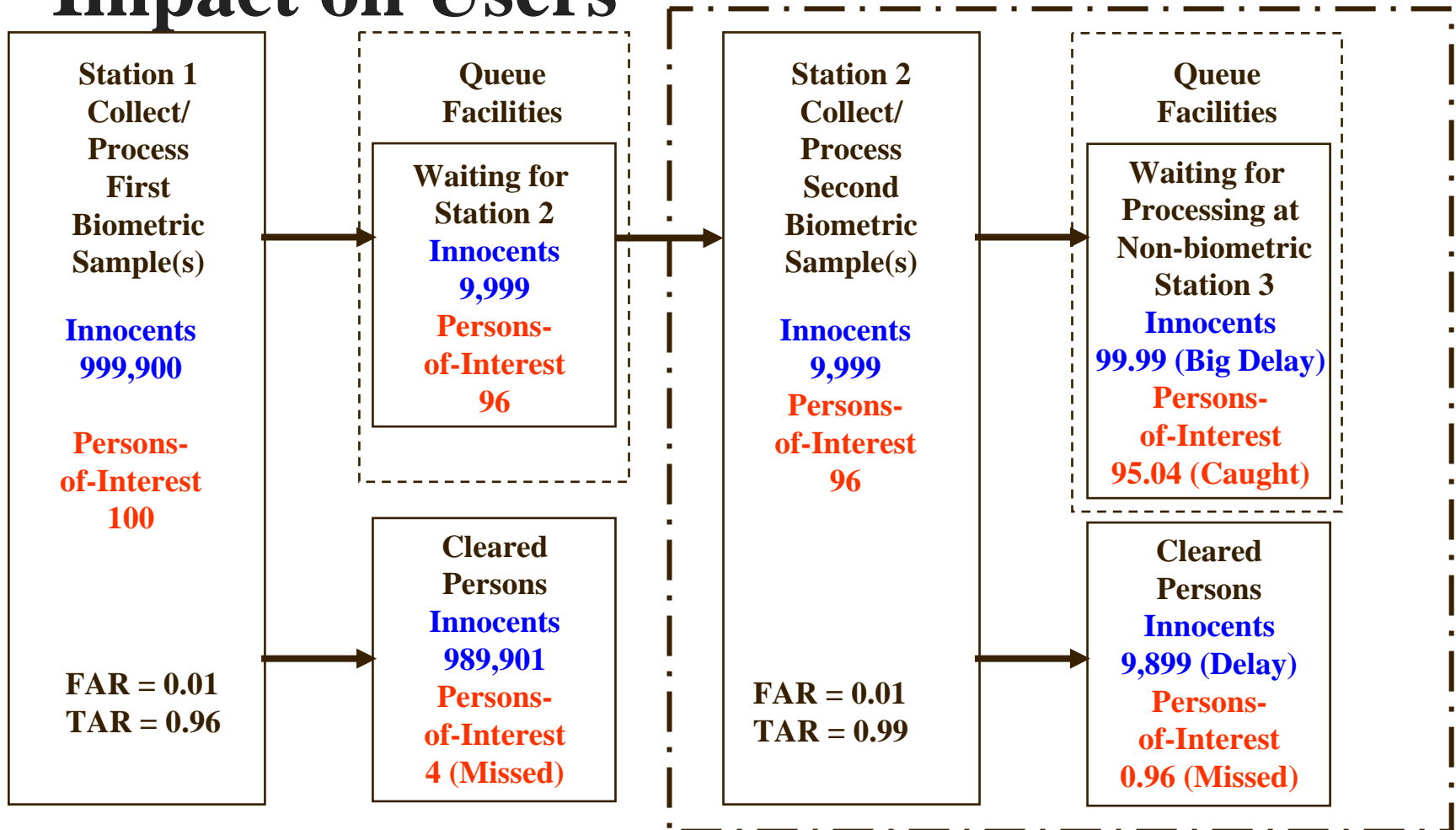


# ROC Analysis of Multi-biometric Fusion (NIST BSSR1 Face and Finger Data)



ROC = Receiver Operating Characteristic

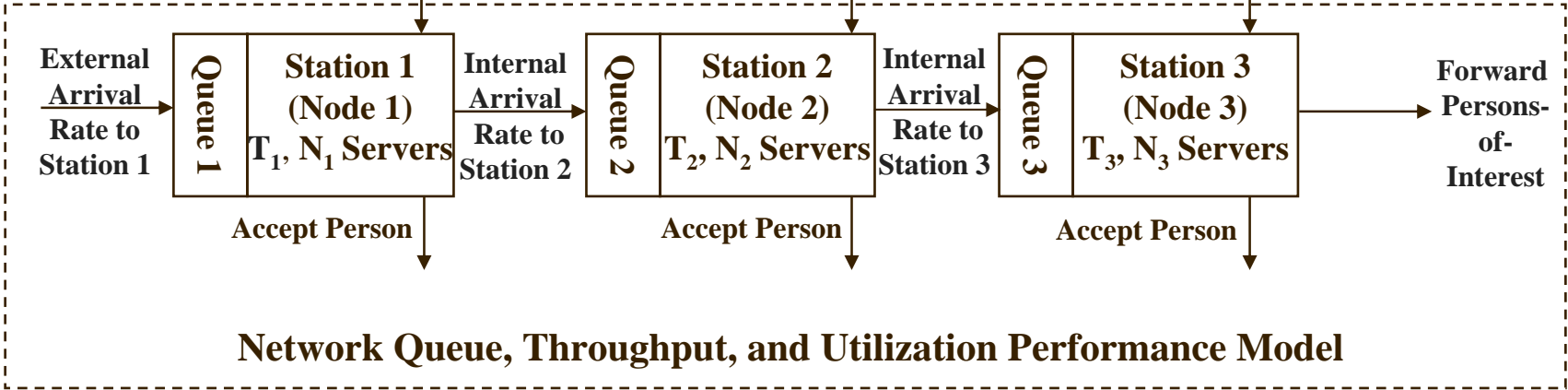
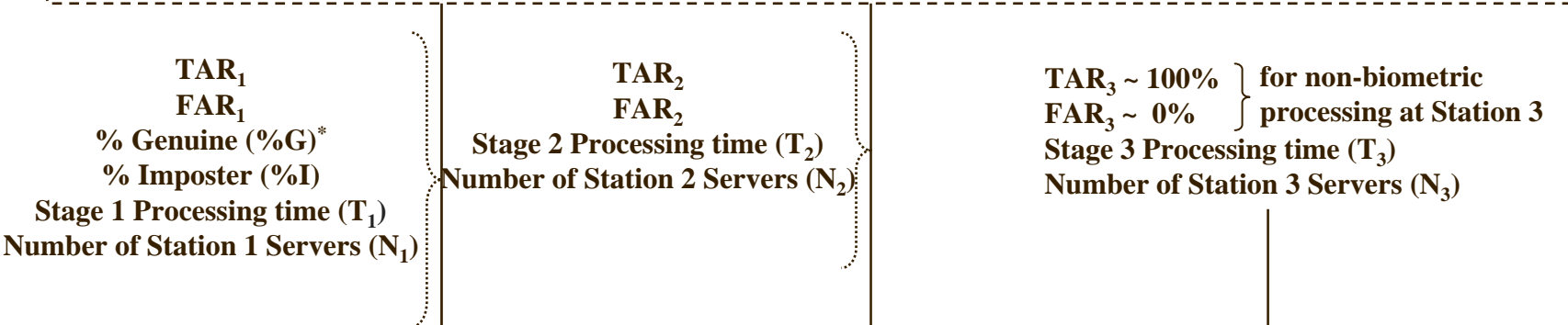
# Notional Watch List Example — Impact on Users



- 2-stage approach (all samples from 1%)
  - 5 persons-of-interest missed
  - 100 innocents need further processing
- 1-stage approach (dashed box only; all samples from 100%)
  - 1 person-of-interest missed
  - 9,999 innocents need further processing

# Watch List Example – Integrated Accuracy and Queuing Model

## Accuracy Performance Model for Biometric Systems



## Network Queue, Throughput, and Utilization Performance Model

\* For a watch list application, a “genuine” is a *person-of-interest*; for an access control system, a “genuine” is an employee.

# Notional Watch List Example – Impact on Network (Steady State Expectations)

<b>Model Input</b>	<b>Station #1</b>	<b>Station #2</b>	<b>Station #3</b>
External Passenger Arrival Rate (# per hour)	1200	NA	NA
% Genuine (% Persons-of-Interest)	0.01%	NA	NA
% Impostors (% Innocents)	99.99%	NA	NA
TAR (%)	96.0%	99.0%	100.0%
FAR (%)	1.0%	1.0%	0.0%
(Planned) Number of Passengers Serviced at Each Server (# per hour)	60	20	3
(Planned) Number of Servers in Service at Each Station	24	4	2

<b>Model Output</b>	<b>Station #1</b>	<b>Station #2</b>	<b>Station #3</b>
Passenger Arrival Rate (# per hour)		12.11	0.23
Expected Number of Passengers in the System	21.5	0.6	0.1
Waiting in the Queue for Service	1.5	0.001	0.0001
In Service (Processing)	20.0	0.6	0.1
Expected Time Passenger is Delayed by Waiting and Service (minutes)	1.1	3.0	20.0
Waiting in the Queue for Service (minutes)	0.1	0.003	0.03
In Service (Processing) (minutes)	1.0	3.0	20.0
Server Utilization (%)	83.3	15.1	3.90

Reference: Gross, D. and Harris, C., *Fundamentals of Queueing Theory*, 3rd Edition, Wiley

# Conclusions

- **A combined biometric system accuracy and queuing model can be used to analyze and quantify the impact of accuracy on**
  - **Identifying persons-of-interest**
  - **User time transiting the system**
  - **Utilization of resources**
  - **Required personnel costs**
- **Elements contributing to the system “cost function” must be balanced based upon operational conditions and performance requirements**
- **Such a model can be used both to design a system for baseline operations as well as an operational tool to adjust system parameters (i.e., accuracy vs. throughput) in response to off nominal workload conditions.**

# Further Information

## Reference

Korves, H., L. Nadel, B. Ulery, and D. Masi, “Multi-biometric Fusion: From Research to Operations”, Sigma, Mitretek Systems, Summer 2005, pp. 39-48,

<http://www.mitretek.org/home.nsf/Publications/SigmaSummer2005>

## Contact

Lawrence D. Nadel, Ph.D.

Mitretek Systems

Phone: (703) 610-1677

Email: [nadel@mitretek.org](mailto:nadel@mitretek.org)

Web: <http://www.mitretek.org>