DHS Science & Technology:

Federal Identity Research Needs: What's Left to Accomplish?

Mr. Christopher Miles, Biometrics Program Manager
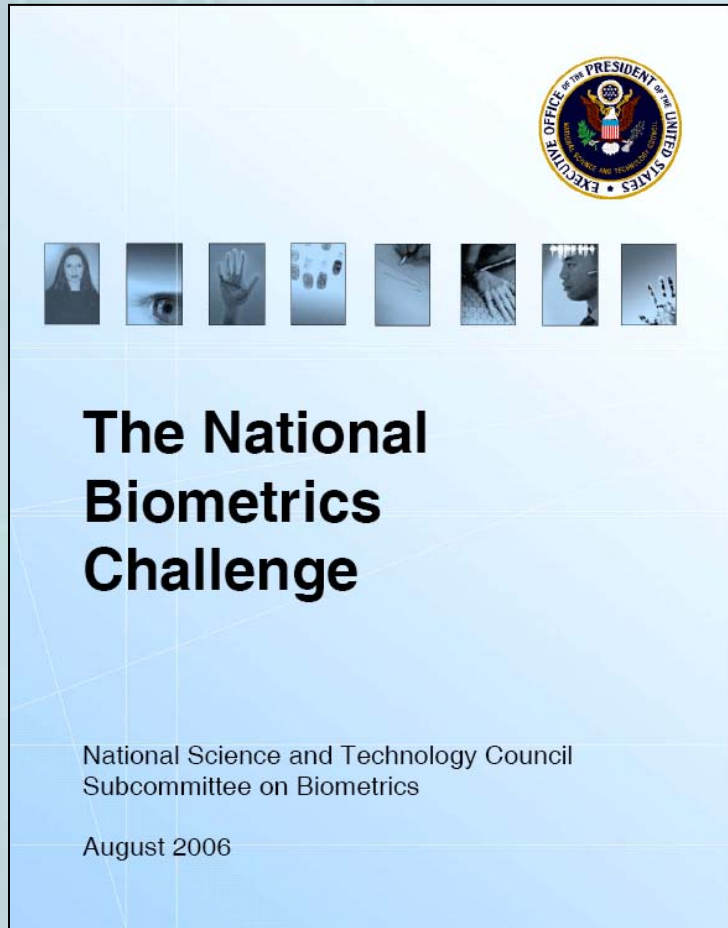**Human Factors/Behavioral Sciences Division**

Science and Technology Directorate
Department of Homeland Security

October 18, 2010

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The National Biometrics Challenge

The National Biometrics Challenge

National Science and Technology Council
Subcommittee on Biometrics

August 2006

- Released in August 2006
- Serves as a robust list of common challenges
- Provides an analysis of:
  - Unique attributes of biometrics
  - Market forces and societal issues
  - Advances required for next-generation capabilities
  - Communications and Privacy
  - Government's Role in Biometrics

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Critical Priorities

RDT&E that Absolutely Must be Done to Accomplish Critical Needs:

- Fast and Intuitive Rolled-Equivalent Fingerprints

- Improved Traditional Sensors

- Traditional Sensors in Mobile and Harsh Environments

- Stand-off Face and Iris Sensors and Matching Algorithms

- Multi-Modal Biometrics in Ideal and Non-Ideal Conditions

- Middleware Techniques/Standards for "Plug-and-Play" Sensors

- Test & Evaluation of Traditional Sensors and Algorithms

- Analysis of System Scalability Issues and Research

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Necessary Priorities

RDT&E that Must be Done to Accomplish Needs:

- Revocable/Replaceable Biometrics

- Enhanced Non-Traditional Sensors and Algorithms

- Automated Environment-Adjusting Sensors

- Enhancing Sub-Optimal Data (Improving Data Quality)

- Lights-Out, Real Time, Latent Screening

- Collection/Analysis/Feedback of Large Perimeter Security/Chokepoints

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Recommended Priorities

RDT&E that Adds Additional Technology Features:

- Enhanced Traditional Algorithms

- Enhanced Non-Traditional Algorithms

- Contactless and/or Self-Sterilizing Contact Fingerprint Sensors

- Application-Based Scenario and Performance Testing

- Human Factors Analysis and Future Adoption Guidelines

- Common Applications Return on Investment (ROI) Models

- Portable matching-verification-credentialing (match on card, non-fixed locations, etc.)
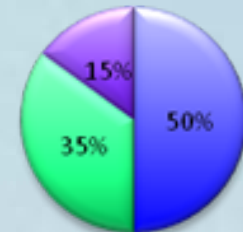
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# Multibiometric Framework Study: *Ten Year Execution Plan*

Project Plan:

- Factors/Drivers for the Research Plan:
  - Support to DHS stakeholders and programs
  - Unique HFD multibiometric fusion research niche
  - Assesses multibiometric fusion capabilities
  - Integrates existing DHS research portfolio projects
  - Incorporates necessary flexibility to be adaptable and scalable in a manageable timeframe

Portfolio Class Breakdown Phase I (2010-2012)
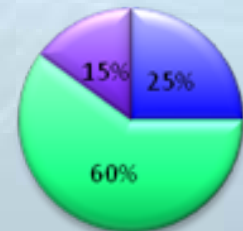
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Portfolio Class Breakdown Phase II (2013-2015)

15%
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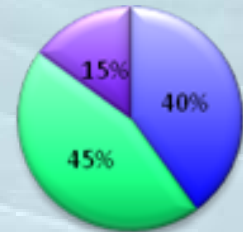
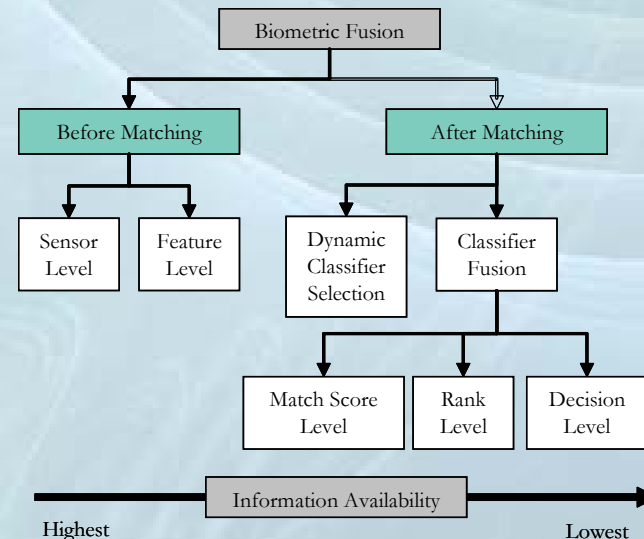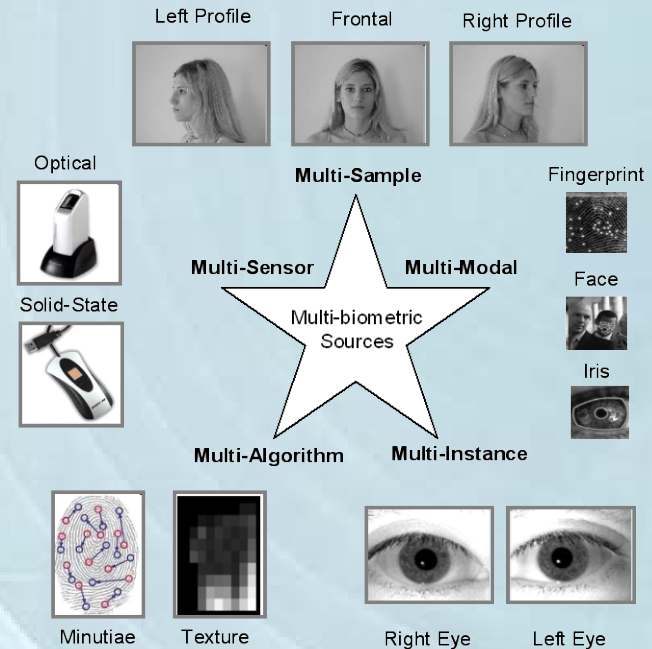**Portfolio Class Breakdown Phase III (2016-2018)**

15%
25%
60%

- Basic Research
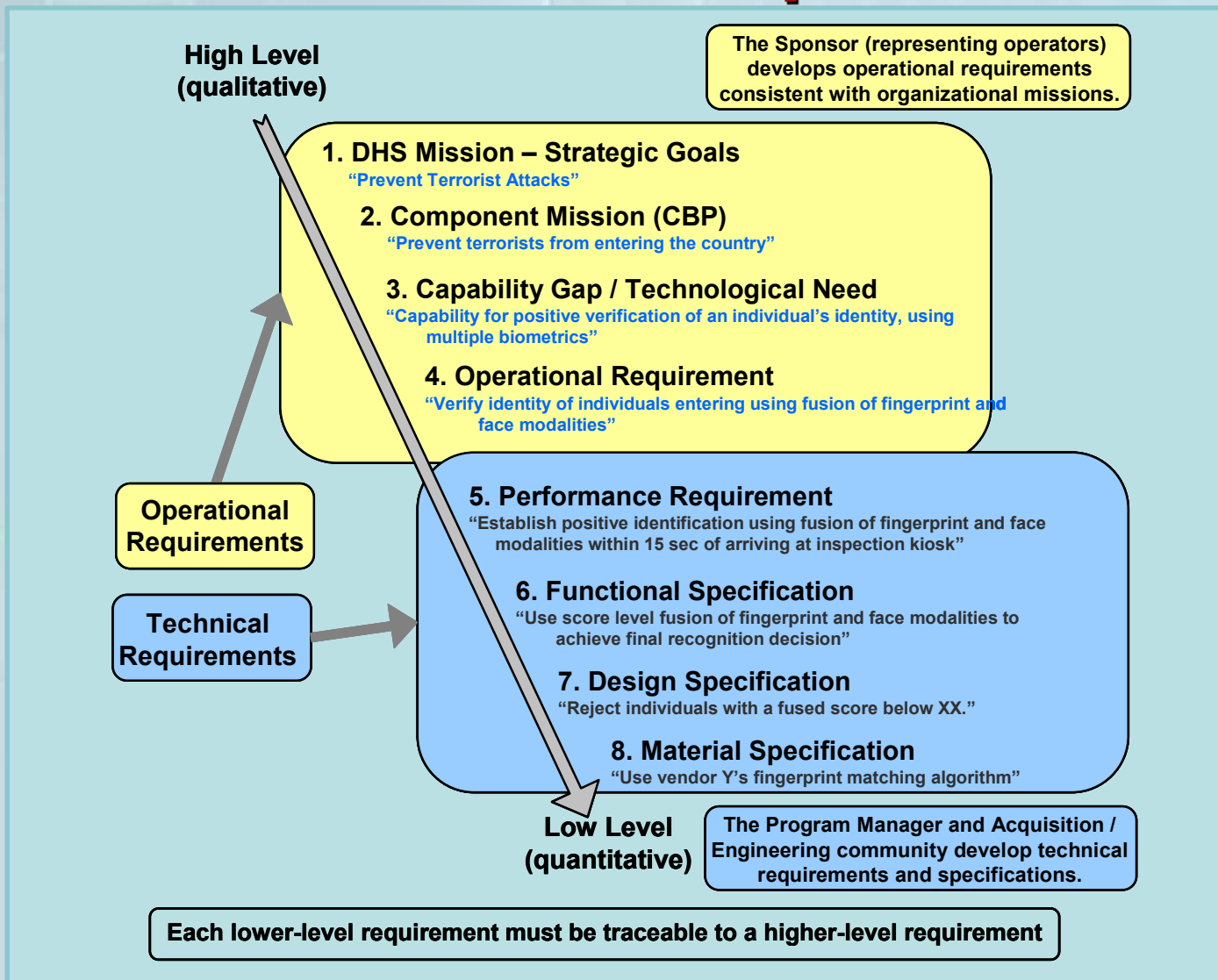- Product Transition
- Innovative Capabilities

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What is Multibiometrics Fusion?

Characteristic	Definition
1. Universality	Every individual accessing the application should possess the trait.
2. Uniqueness	The given trait should be sufficiently different across individuals comprising the population.
3. Permanence	The biometric trait of an individual should be sufficiently invariant over a period of time with respect to the matching algorithm. A trait that changes significantly over time is not a useful biometric.
4. Measurability	It should be possible to acquire and digitize the biometric trait using suitable devices that do not cause undue inconvenience to the individual. Furthermore, the acquired data should be amenable to processing in order to extract representative feature sets.
5. Performance	The recognition accuracy and the resources required to achieve that accuracy should meet the constraints imposed by the application.
6. Acceptability	Individuals in the target population that will use the application should be willing to present their biometric trait to the system.
7. Circumvention	This refers to the ease with which the trait of an individual can be imitated using artifacts (e.g. fake fingers), in the case of physical traits, and mimicry, in the case of behavioral traits.

Left Profile Frontal Right Profile

Multi-Sample

Optical Fingerprint

Multi-Sensor   Multi-Modal

Solid-State   Face

Multi-biometric Sources

Iris

Multi-Algorithm   Multi-Instance

Minutiae   Texture   Right Eye   Left Eye

Biometric Fusion

Before Matching | After Matching

Sensor Level | Feature Level | Dynamic Classifier Selection | Classifier Fusion

Match Score Level | Rank Level | Decision Level

Information Availability

Highest ———————————→ Lowest

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A. Ross, K. Nandakumar, and A.K. Jain. *Introduction to Multibiometrics* and *Handbook of Multibiometrics*.

Multibiometric Requirements

High Level (qualitative)

1. DHS Mission – Strategic Goals
"Prevent Terrorist Attacks"

2. Component Mission (CBP)
"Prevent terrorists from entering the country"

3. Capability Gap / Technological Need
"Capability for positive verification of an individual's identity, using multiple biometrics"

4. Operational Requirement
"Verify identity of individuals entering using fusion of fingerprint and face modalities"

Operational Requirements

Technical Requirements

5. Performance Requirement
"Establish positive identification using fusion of fingerprint and face modalities within 15 sec of arriving at inspection kiosk"

6. Functional Specification
"Use score level fusion of fingerprint and face modalities to achieve final recognition decision"

7. Design Specification
"Reject individuals with a fused score below XX."

8. Material Specification
"Use vendor Y's fingerprint matching algorithm"

Low Level (quantitative)

The Program Manager and Acquisition / Engineering community develop technical requirements and specifications.

Each lower-level requirement must be traceable to a higher-level requirement

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How to Prioritize Multibiometric Work?

	Multi-biometric Fusion Topics (click to view description)	Research Plan Inclusion Score (RPIS)	DHS Operational Relevance (DHSO)	Maturity (MATU)	Consumer Stakeholder Score (CSSS)	Normalized DHSO	Normalized MATU	Normalized Impact	Impact on Roles / Characteristics							
									Universality (UNIV)	Uniqueness (UNIQ)	Permanence (PERM)	Measurability (MEAS)	Performance Accuracy (PERA)	Performance Efficiency (PERE)	Acceptability (ACCE)	Circumvention (CIRC)
1	Robust and Novel Acquisition	0.951	3	3	0.967	1.000	1.000	0.719	3	2	2	3	3	3	3	4
2	Dynamic "Decisional" Fusion	0.942	3	3	0.967	1.000	1.000	0.656	4	2	2	2	4	1	3	3
3	Hierarchical Fusion	0.841	3	2	1.000	1.000	0.667	0.719	3	3	3	3	4	3	2	2
4	Vetting Operational System Performance	0.827	3	2	1.000	1.000	0.667	0.625	2	2	2	2	4	2	4	2
5	Quality Enhanced Fusion Schemes	0.822	3	2	1.000	1.000	0.667	0.594	2	2	2	3	4	2	2	2
6	Building Non-Fingerprint Watchlists	0.816	3	2	0.967	1.000	0.667	0.594	4	2	3	2	4	1	1	2
7	Dealing with Missing Data	0.813	3	2	1.000	1.000	0.667	0.531	2	2	2	2	4	1	2	2
8	Fusion Incorporating Meta / Ancillary Data	0.812	2	3	0.957	0.667	1.000	0.469	2	2	2	2	4	0	1	2
9	Multi-biometric PACS / LACS	0.793	3	2	0.852	1.000	0.667	0.594	2	2	2	2	3	3	3	2
10	Developing Multi-biometric Testing Databases	0.781	3	2	0.861	1.000	0.667	0.500	2	2	2	2	2	2	2	2
11	Hybrid Fusion	0.731	2	2	0.902	0.667	0.667	0.781	4	4	4	4	4	0	1	4
12	Observing the Biometric Menagerie	0.730	2	2	0.967	0.667	0.667	0.688	4	4	2	4	2	2	2	2
13	Biometric Capacity Analysis	0.725	2	2	0.967	0.667	0.667	0.656	2	2	2	2	3	2	4	2
14	Multi-modal Fusion	0.724	3	1	1.000	1.000	0.333	0.719	4	4	4	2	4	0	1	4
15	Mitigation of Interagency Data Sharing Issues	0.722	2	2	1.000	0.667	0.667	0.594	2	2	2	2	3	4	2	2
16	Feature-level Fusion	0.717	2	2	0.902	0.667	0.667	0.688	3	3	2	2	4	2	2	4
17	Sensor-level Fusion	0.717	2	2	0.924	0.667	0.667	0.656	3	2	2	4	3	2	2	3
18	Multi-biometric Standards Activities	0.713	2	2	1.000	0.667	0.667	0.531	2	2	2	2	2	3	3	1
19	Rank-level Fusion	0.711	2	2	0.967	0.667	0.667	0.563	2	2	2	2	3	2	2	3
20	Multi-instance Fusion	0.704	3	1	0.946	1.000	0.333	0.656	4	3	2	2	3	2	2	3
21	Multi-sensor Fusion	0.703	2	2	0.902	0.667	0.667	0.594	2	2	2	4	3	1	2	3
22	Addressing Multi-biometric Vulnerabilities	0.702	2	2	0.924	0.667	0.667	0.563	2	2	2	2	3	1	2	4
23	Model Estimation / Update Schemes	0.680	2	2	0.837	0.667	0.667	0.531	2	2	2	2	4	1	2	2
24	Multi-biometric Indexing Systems	0.655	2	2	0.663	0.667	0.667	0.594	2	2	2	2	2	4	3	2
25	Global / Local Databases	0.627	2	2	0.641	0.667	0.667	0.438	2	2	2	2	0	4	0	2
26	Legal Issues	0.618	1	2	1.000	0.333	0.667	0.563	2	2	2	2	2	2	4	2
27	Score-level Fusion	0.615	2	1	1.000	0.667	0.333	0.656	3	3	2	2	4	2	2	3
28	Decision-level Fusion	0.601	2	1	1.000	0.667	0.333	0.563	2	2	2	2	3	2	2	3
29	Multi-algorithm Fusion	0.581	2	1	0.902	0.667	0.333	0.563	2	2	2	3	3	2	2	2
30	Multi-sample Fusion	0.577	2	1	0.859	0.667	0.333	0.594	2	2	2	3	3	2	2	2
31	User-Specific Modeling	0.520	1	2	0.511	0.333	0.667	0.563	2	2	2	2	4	0	2	3

Ranges					Weight
Research Plan Inclusion Score (RPIS)	0-1 (higher score indicates greater likelihood to be included)				n/a
DHS Operational Relevance (DHSO)	Not Relevant = 0	Slightly Relevant = 1	Highly Relevant = 2	Required by PM / Stakeholder = 3	0.20
Maturity (MATU)	Little Room for Future Work = 0	Highly Developed with Opportunities = 1	Examined but Immature = 2	Completely Novel = 3	0.30
Consumer Stakeholder Score (CSSS)	0-1 (see individual topic pages for non-normalized value breakdown)				0.35
Impact on Characteristics (UNIV, UNIQ, PERA, etc.)	Highly Negative = 0	Slightly Negative = 1	Unchanged = 2	Slightly Positive = 3	Highly Positive = 4	0.15
					1.00

Labels			
Portfolio Research Class	Basic Research = BR	Product Transition = PT	Innovative Capabilities = IC
Portfolio Research Group	Collection / Acquisition Systems = CS	Data Quality & Enhancement = DQE	Next Generation Algorithms & Modalities = NGAM
	Information Fusion = IF	Data Sharing & Architecture = DSA	Performance Management & Tracking = PMT

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How to Prioritize Multibiometric Work?

- **Multi-Biometric Fusion Research Topic Priority Matrix Tool**
  used to evaluate topics for consideration
  - DHS Operational Relevance   -- Maturity of Research
  - Consumer Stakeholder Score   -- Impact on Characteristics of Biometric System

	Multi-biometric Fusion Topics (click to view description)	Research Plan Inclusion Score (RPIS)	DHS Operational Relevance (DHSO)	Maturity (MATU)	Consumer Stakeholder Score (CSSS)
1	Robust and Novel Acquisition	0.951	3	3	0.967
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8	Fusion Incorporating Meta / Ancillary Data	0.812	2	3	0.957
9	Multi-biometric PACS / LACS	0.793	3	2	0.852
10	Developing Multi-biometric Testing Databases	0.781	3	2	0.861
11	Hybrid Fusion	0.731	2	2	0.902
12	Observing the Biometric Menagerie	0.730	2	2	0.967
13	Biometric Capacity Analysis	0.725	2	2	0.967
14	Multi-modal Fusion	0.724	3	1	1.000
15	Mitigation of Interagency Data Sharing Issues	0.722	2	2	1.000

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- **Multi-Biometric Fusion Research Topic Priority Matrix Tool**
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20	Multi-instance Fusion	0.704	3	1	0.946
21	Multi-sensor Fusion	0.703	2	2	0.902
22	Addressing Multi-biometric Vulnerabilities	0.702	2	2	0.924
23	Model Estimation / Update Schemes	0.680	2	2	0.837
24	Multi-biometric Indexing Systems	0.655	2	2	0.663
25	Global / Local Databases	0.627	2	2	0.641
26	Legal Issues	0.618	1	2	1.000
27	Score-level Fusion	0.615	2	1	1.000
28	Decision-level Fusion	0.601	2	1	1.000
29	Multi-algorithm Fusion	0.581	2	1	0.902
30	Multi-sample Fusion	0.577	2	1	0.859
31	User-Specific Modeling	0.520	1	2	0.511

A Ten Year Strategic Plan

Phase I

1. Dynamic Decisional Fusion
2. Hierarchical Fusion
3. Quality Enhanced Fusion Schemes
4. Fusion Incorporating Meta / Ancillary Data
5. Hybrid Fusion
6. Observing the Biometric Menagerie
7. Biometric Capacity Analysis
8. Sensor Level Fusion
9. Rank Level Fusion

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1. Vetting Actual System Performance
2. Building Non-Fingerprint Watchlists
3. Developing Multi-Biometric Testing Databases
4. Multi-Biometric PACS / LACS
5. Multi-Modal Fusion
6. Mitigation of Interagency Data Sharing Issues
7. Global / Local Databases

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1. Robust and Novel Acquisition
2. Dynamic Decisional Fusion

Phase II

1. Dealing with Missing Data
2. Multi-Sensor Fusion
3. Addressing Multi-Biometric Vulnerabilities
4. Model-Estimation / Update Schemes
5. Multi-Biometric Indexing Schemes
6. Additional Basic Research Activity
7. Additional Basic Research Activity

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1. Hierarchical Fusion
2. Quality Enhanced Fusion Schemes
3. Fusion Incorporating Meta / Ancillary Data
4. Hybrid Fusion
5. Observing the Biometric Menagerie
6. Sensor-Level Fusion
7. Rank Level Fusion
8. Additional Product Transition Research Activity

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1. Robust and Novel Acquisition
2. Additional Innovative Capabilities Research Activity

Basic Research
Product Transition
Innovative Capabilities

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A Ten Year Strategic Plan

Robust and Novel Acquisition: Innovative methods of acquiring biometric information and novel or emerging biometric modalities.

Fusion Approaches:

    Dynamic Decisional Fusion

    Hierarchical Fusion

    Quality Enhanced Fusion Schemes

    Fusion Incorporating Meta/Ancillary Data

    Hybrid Fusion

    Sensor-Level Fusion

    Rank-Level Fusion

    Multi-Sensor Fusion

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A Ten Year Strategic Plan

Observing the Biometric Menagerie: Careful examination of match score distributions as well as the observance and analysis of problematic subjects.

Biometric Capacity Analysis: Analysis of the theoretical system capacity of the template representation and the biometric variations observed during inter and intra-class comparisons.

Model Estimation/Update Schemes: Modeling update schemes to trigger the re-evaluation of system thresholds,   re-estimation of relevant densities, or selection of different algorithms for classification.

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A Ten Year Strategic Plan

Multi-Biometric Indexing Systems: Investigating the ability to index based on multiple biometric sources to minimize the penetration rate (percentage of the database searched) without adding additional errors due to incorrect indexing.

Addressing Multi-Biometric Vulnerabilities: Analysis of circumvention approaches for multibiometric identification, verification, and watchlist systems.

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Other Research Challenges

Cross-discipline Basic Research:
- The role of human identity in security
  - combining biometrics and cryptography
- The acceptability and usability of biometrics in DHS' applications
  - combining biometrics with mathematics, cognitive psychology, industrial design and/or behavioral sciences
- The forensic proof of automated biometric systems
  - combining biometrics and forensic or medical sciences
- The acquisition of useful biometric samples independent of the environment
  - combining biometrics with complimentary imaging disciplines

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DHS S&T Biometrics Program Timeline

FY 08	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16

Transition: People Screening IPT

- CG/Mona Pass
- Commercial Data Sources
- Mobile Biometrics
- Multi-modal Biometrics (Face/Iris)
- Rapid & Low-Cost DNA
- Ten-Print Capture
- Remote Biometric Capture

Innovation

- Contactless Fingerprinting (3)

Research

- Mobile SBIR (3)
- Mobile SBIR ΦII (2)
- Remote SBIR (3)
- Remote SBIR ΦII
- Rapid DNA SBIR (3)
- Rapid DNA ΦII (2)
- Synthetics SBIR (3)
- Synthetics ΦII
- Multi-Biometric Framework Study
- Multiple-Biometrics Grand Challenge/MBE
- ITR Fusion/Decision Mgmt
- Center for Identity Technology Research (CITeR)
- NIST/MBARK
- Sandia Basic Research Technical Working Group
- Biometrics Basic Research

■ = Funded by other sources

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Indispensable Resources
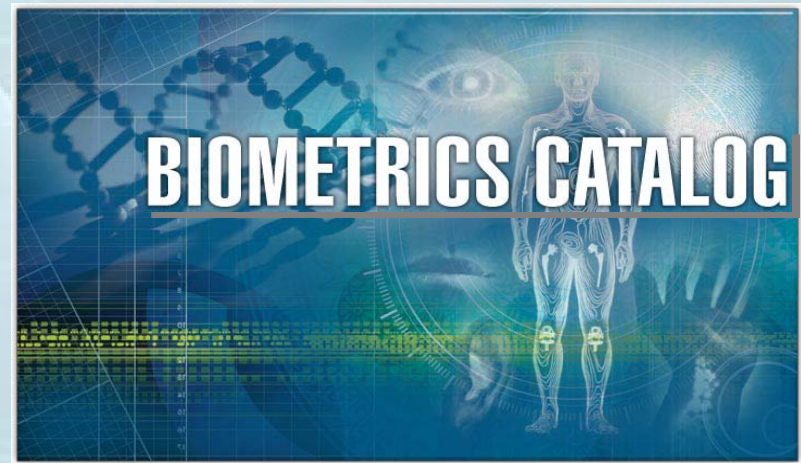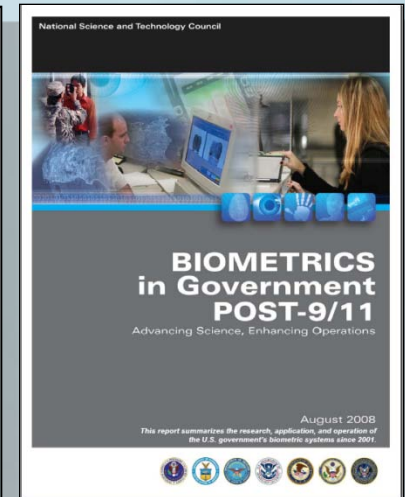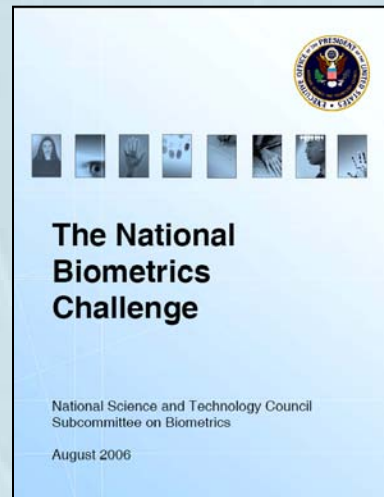
www.Biometrics.gov
Central source on Federal government biometrics-related activities

www.BiometricsCatalog.org
U.S. Government-sponsored database of public information about biometric technologies kept current by its users, who add information as it becomes available – Free to use and update

www.Biometrics.org
Biometrics Consortium web site with free discussion bulletin board and annual conference news

The National Biometrics Challenge

National Science and Technology Council Subcommittee on Biometrics

August 2006

National Science and Technology Council

BIOMETRICS in Government POST-9/11
Advancing Science, Enhancing Operations

August 2008
This report summarizes the research, application, and operation of the U.S. government's biometric systems since 2001.

BIOMETRICS CATALOG

Biometrics.gov

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