Data Fusion Group Perspective

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Data Fusion Group

History

- **Established by Joint Directors of Laboratories (JDL), Technology Panel for C3 (TPC3), 1985**
- **JDL Disestablished Oct. 1997**
- **TPC3 replaced by DDR&E Information Systems and Technology Panel (IST)**
- **DFG reports to IST Decision Making Subpanel**

Purpose

To Enhance the Efficiency of Individual and Joint Service Data Fusion Programs Through:

- **Exchange of Technical Information within US and International Forums**
- **Improvement of Coordination and Cooperation**
- **Initiation of New Multiservice Cooperative Research and Technology Demonstrations**
- **Provide Monitoring and Feedback Functions within DoD (S & T Reporting)**
- **Provide Education and Coordination Mechanisms for DoD and non-DoD Users, Developers and Theoreticians**

DFG Membership

Frank White (SSC-SD), Chairman

Members

Richard Antony (VGS)
Fred McHugh (NSA)
Bill Doig (SAIC)
Dave Hall (ARL/PSU)
Phil Hanselman (AFRL/SNAS)
Mike Hinman (AFRL/IFEA)
Joe Karakowski (CECOM)
Otto Kessler (DARPA)
Stan Lewantowicz (ERIM)
Jim Llinas (Multisource)
Alan Steinberg (ERIM)
Col. Clint Wallace (ASC2ISRC)

Associates

Joe Antonik (ACC)
Don Brown (Univ of VA)
Ken Campbell (SSC-SD)
Ray Freeman (ASASPO)
Frank Gorecki (Boeing)
Ed Jahn (SSC-SD)
Dave Johnson (ONR)
Paul Kolodzy (Sanders)
Ed Nozawa (Lockheed)
Dave Procter (MITRE)
Tom Schwendtner (Aerospace)
Pete Smyton (MITRE)
Ed Waltz (ERIM)

International Associates

Mark Bedworth (DERA, UK)
Jane O'Brien (DERA, UK)
John Percival (DSTO, Australia)

DFG Activities and Products

Products

- **Symposium (DFS / NSSDF)**
- **Model**
- **Taxonomy**
- **Lexicon**
- **Survey**

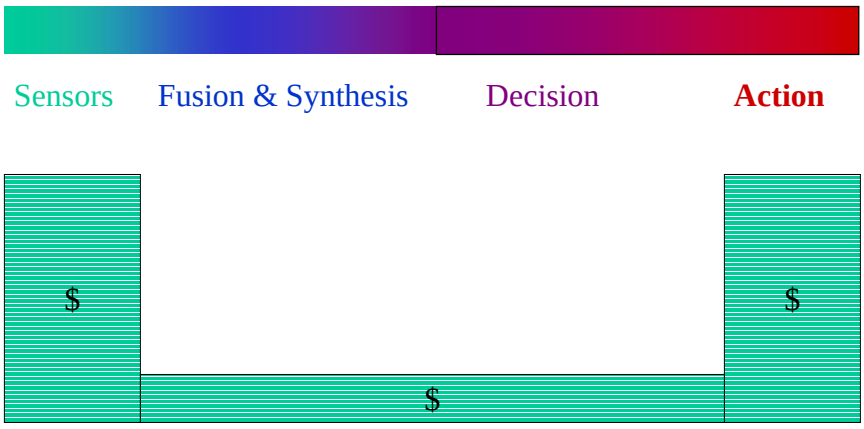
Activities

- **Special Interest Groups**
- **Coordination Activities**
- **Information Analysis Center**
- **International Community**
  - **International Fusion Society**
  - **EuroFusion**
  - **TTCP Fusion Group**

Fusion and Information - Key Relationship

- Age of the Mechanized Observer - Data without meaning (Boorstin)
- Age of the Democratic Information Systems (Gould)
  - Internet, Intelink, Cable Networks News
    - Can't establish Priorities on Data
    - Trouble Transforming Data into Information, Knowledge and Ultimately Understanding.
    - Particularly Troubling for Hierarchical Military Structures

Investment "BarBell" in an "end to end" process



PARTIAL LIST OF DOD FUSION EFFORTS

- J2P DISA WORKING GROUP ON CORRELATION & FUSION
  - GCCS (CFWG & JIFWG)
  - JMCIS (NAVY)
  - TBMCS (AF- Former CIS)
  - ASAS (ARMY)
  - IAS (MARINE)
  - DODIIS SUNSHINE (DIA)
- FORCE WARFARE SYSTEMS ENGINEERING BOARD (CSFAB - Combat Systems Functional Allocation Board)
  - COMMON OPERATIONAL (ORGANIC/INORGANIC) PICTURE
  - COMBAT ID
- WARGODDESS (NSA)
- INTELLIGENCE FUSION (JBC)
- DYNAMIC DATA BASE (DARPA)
- MERCHANT TRACKING (ONI)
- PROJECT CORRELATION (USAF TENCAP)
- DATA FUSION FACILITY (NRO)
- MODERNIZED INTELLIGENCE DATA BASE (MIDB)
  - MERGING DYNAMIC AND STATIC INFORMATION
  - TACTICAL AND STRATEGIC FUSION
- DATA FUSION STAKEHOLDERS GROUP
  - Spearheaded by ASC2ISRC (Wallace)

Fusion Efforts Proliferate -
Addressing Policy and Technology

Need for Coordination
State of the Community

- **Everyone thinks Fusion is Unique to their Program**
  - **Pervasive nature of Data Fusion is Good/Bad News**
  - **Importance is Recognized / Leveraging is Overlooked**
- **Sense of Independent Requirements (Application Independence) by Systems Developers**
- **The Commonality of "Core" Fusion Processes is not Widely Recognized**
- **No Community Process for Evaluating Fusion Operationally or Technically**

The community lacks some important attributes:
- common awareness of key technologies
- infrastructure services and products
- active agents for coordination

Needed: Technology to Resolve Deficiencies in Data Fusion Systems

- **EFFECTIVENESS:**
  - **Performance:** ***Lack of timely, accurate target & situation awareness***
  - **Focus:** ***Information not tailored to decision-maker's needs***
  - **User Confidence:** ***Can't assess information quality***
  - **Interoperability:** ***Legacy systems can't talk to one another***
  - **Data Exploitation:** ***Reported data doesn't include some types of useful data***
- **AFFORDABILITY:**
  - ***Every new system is designed from scratch***

Key Technology Needs
(A Sampling)

- **Theoretical Foundations**
  - **General Theory of Data Fusion**
  - **Canonical Forms for Fusion Processes**
  - **Linguistic Algebra**
  - **Cognitive Models**
- **Reasoning Systems Development**
  - **Spatial Temporal Reasoning**
  - **Machine Reasoning for Situation Assessment**
  - **Automated Template Authoring**
- **Data and Knowledge Bases for Fusion Processing**
  - **Spatial-Object Oriented DBMS**
  - **Natural Language Interface Support for Decision Maker**
- **Algorithm & Model Development**
  - **Library of Tools**
  - **Mapping of Problems to Solution Sets**
  - **Exploitation of Parallelism**

Needed: An Underlying Framework for Data Fusion Development - An Infrastructure

To accelerate operational introduction of data fusion by providing:

- **A common environment for coordination and communication**
- **Standardization and interoperability support to key technologies**
- **An environment for comparing benefits of alternative techniques**
- **Performance criteria for transition of products**

These needs parallel similar evolution in related elements which are maturing:

For example :

- *TCP/IP Networks and Services (eg: INTELINK) are Providing an Architectural Framework for Information Sharing Including Intelligence*
- *DII COE and GCCS have the Potential for Creating a Common Development and Operating Environment*
- *Large B/W Comms (e.g. GBS) can move massive amounts of data*

Infrastructure: Services, Products and Activities

- **State-of-the -Art Reports**
- **Critical Reviews and Technology Assessments**
- **Current Awareness**
- **Special Studies/Tasks**
- **Technical Inquiry Service**
- **Abstracts and Indexes**
- **Scientific and Engineering Reference Works**
- **Bibliographic Inquiry Service**
- **Technical Conference/Interagency Committee Organization and Administration**
- **Software Clearinghouse**

An IAC (*Information Analysis Center*) as defined by DoD could provide such services

FUSIAC

(*Data Fusion Information Analysis Center)*

Draft Objectives and Responsibilities

- Assist in coordinating joint program plans
- Recommend high payoff areas of data fusion research and technology for multi-service attention
- Identify critical data fusion issues, deficiencies and overlapping efforts
- Expedite transfer of data fusion technologies between Services
- Establish special interest groups to focus technology functions
- Identify new opportunities for interoperability and reliance on a continuing basis
- Develop and maintain a database of on-going work
- Develop and maintain a database of Subject Matter Experts
- Support data fusion in information analysis
- Assess role of international R&D in technologies supportive of data fusion process
- Interface with other organizations as appropriate, other Technical Panels, other coordination bodies
- Develop metrics and methodology for assessing fusion systems

A *Virtual* FUSIAC will stand up under auspices of IRIAC and IATAC

Needed: A Strategy to Coordinate Roles and Responsibilities

- **Functional Needs**
  - **Systems Discipline for Architecture & Engineering**
    - Standards for Acquisition, T&E
    - Data interfaces and commonality
  - **Technology Development**
  - **Information Exchange**
    - Symposia, Workshops, Education, Publications
  - **Data Bases**
    - Avail. for Algorithms, Multi-Source Test Sets, Models, ...
- **Coordination with**

> ASD/C3I
> DDR&E
> Intel Agencies
> CMS
> DISA (DII-COE)
> DARPA
> Services
> Service Labs
> …..

Coordination Challenges

- **To Create a Flexible, Upgradeable Architecture**
  - > Coordination of architecture, standards, interoperability
  - > Leverage COTS
  - > Enable ***evolution***
- **To Effect Rapid Change without Chaos**
  - > Re-engineer RDT&E process to leverage technological advances
  - > Avoid premature / proprietary HW & SW
- **To Implement Evolutionary Acquisition**
  - > Intelligent, timely introduction of new capabilities
  - > Responsive to user needs
  - > Consistent with Interoperability constraints
- **To Create a Spirit of Cooperation**
  - > Encourage/Incentivize cross-organizational cooperation & teaming
  - > Broad, early participation

Underlying Issue: Where is the revolution?

How do we effect major change in the employment and growth of information technologies (some have called it a revolution) without an equivalent cultural change (policies and attitudes)?

Competing Premises:
- DoD is not the primary developer/user of relevant technologies
- Information related technologies have a half life of ~12 months
- Standards are needed to insure compatibility (Joint/Coalition)

Demands:
- Smart leveraging of commercial technology
  Intelligent adaptation for military usage
- Evolution of standards
  Flexible / Rapidly upgradeable / Backwards compatible
- Common usage in functions of
  Planning / Processing / Exploitation / Dissemination

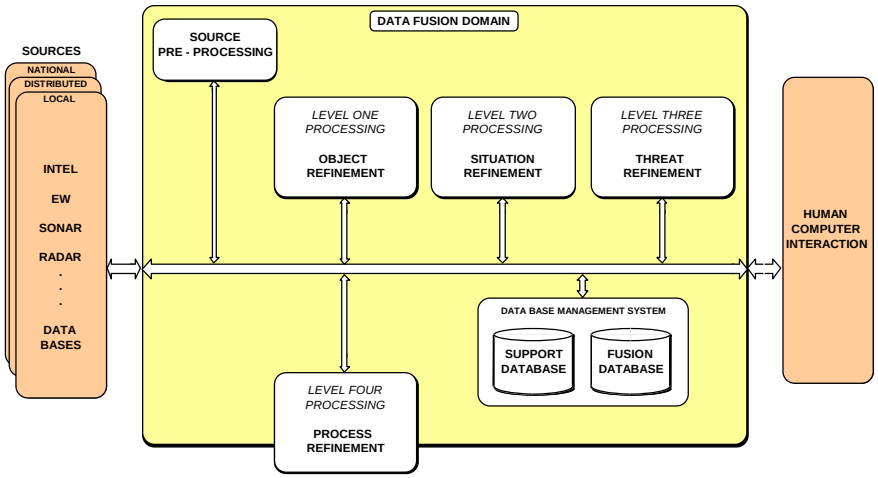
Does this imply a need for:
- ***Changes in acquisition systems / program & platform relationships?***
- ***R&D focus on military's unique requirements?***
- ***Treatment of system integration as a technology?***

What Actions Are we Taking

- **Re-establish the DFG as a Visible Entity under the IST Panel**
  - **Reaffirm the stewardship function of the original JDL/TPC3**
  - **Empowered as an Agent for:**
    - **Policy Coordination**
    - **Technology Proliferation & Integration**
  - **To Create a Coordination Environment which will enable:**
    - **More effective leverage of investment in data fusion research**
    - **Better understanding, test and evaluation of data fusion processes**
    - **More rapid transition of data fusion technologies to fielded systems**
- **Endorse FUSIAC Concept**
  - **Probable reporting line to ASD/C3I**
  - **DFG to act as Steering Group**

BACK-UP SLIDES

DATA FUSION PROCESS



Initial FUSIAC Implementation Actions

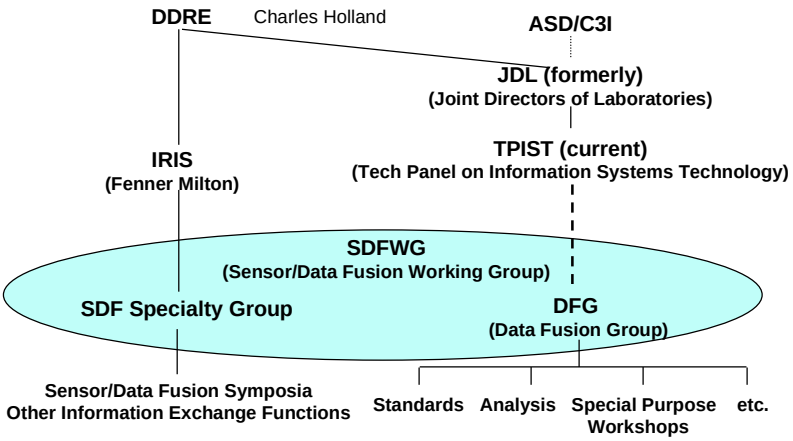
- Gain concept concurrence from ODDR&E, ASD/C^{3}I, NSA, DISA, Joint Staff, and other agencies and activities as required to ensure appropriate support is subsequently provided FUSIAC
- Gain concept agreement between IATAC and IRIA to serve as FUSIAC Team. -- ACTION COMPLETE
- Gain Director of Defense Research and Engineering, USD(A&T) approval for FUSIAC Team concept based on appropriate concurrence.
- Gain initial approval for $1.6M to provide funding for FUSIAC Team core support activities.
- Develop and install an FUSIAC Homepage on Internet.
- Develop and install an FUSIAC Homepage on Intelink(S).
- Develop and install an FUSIAC Homepage on Intelink.
- Gain concept agreement with other DTIC-sponsored DoD IACs to provide support to FUSIAC Team. -- ACTION COMPLETE
- DTIC officially establish team in accordance with ODDR

Potential Initial Activities*

- 6 Months ARO
  - Infrastructure - Facility, Staffing, Security
  - Newsletter
  - Website
  - Project/Technology/Subject Expert Data Base - Structures
- 12 Months ARO
  - State of Art Report
  - Project/Technology/Subject Expert Data Base - Initial Population
  - National Symposium
- 18 months ARO
  - Technique Application & Engineering Guidelines
  - Project/Technology/Subject Expert Data Base - Enhanced

**Depending on Funding and Priorities*

DFG: Organizational Proliferation

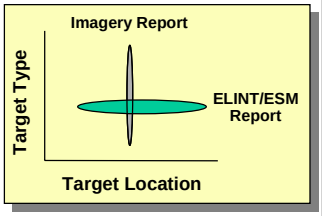


All-Pervasive Nature of Data Fusion
Requires a Unified Organizational Approach

Data Fusion Benefits

Sensor Systems

- **Cross-Sensor Cueing**
  - More efficient search
  - Enhanced detection
    (cued dwells; reduced threshold)
  - Reduced requirements on individual
    sensors (sensitivity, coverage, accuracy)
  - LO techniques (passive cueing of radar; bistatic sensing)
- **Combine Multi-Source/Multi-Discipline Information**
  - Target refinement: location/track, ID
  - Cross-domain imaging (e.g. E-O+SAR)
  - Force structure assessment
  - Own force vulnerability assessment
  - Supports Planning/Plan Execution/Re-planning
- **Maintain Track Continuity: Correlate Time-Separated Observations**
  - Intermittent sensor passes
  - Terrain masking and countermeasures



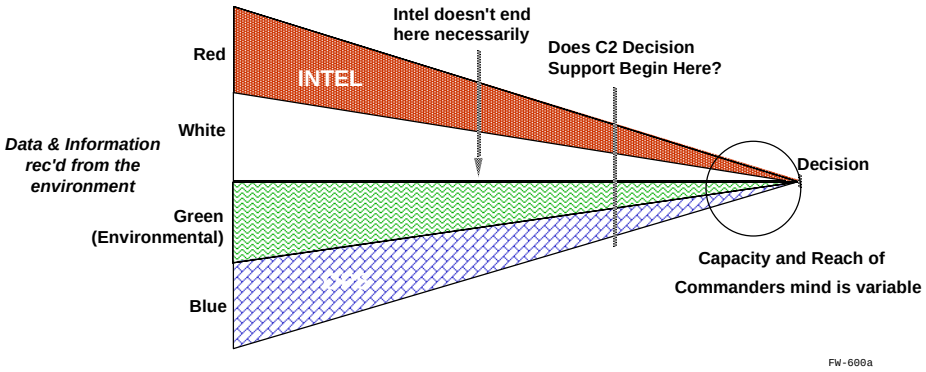
Data Fusion Benefits

Command Systems

- **Formation of Consistent Tactical Picture**
  Integration of sensors, comms, intel, etc.
- **Assessment of Situation/Threats**
  Understanding of Blue distribution and vulnerability
  Awareness of Red capability and intent
- **Enabler for Information Management**
  Flow, Access, Use of Information
- **Decision Support Advisories**
- **Key tool in support of "TPED"**
  (Tasking / Processing / Exploitation / Dissemination)

Data Fusion: Transforms Data into Information and Knowledge

The Key is Seamless FLOW to the Commander - A Person
Our "Boxes" can become artificial restrictions to the Flow



Data → Information → Knowledge → Understanding

Hierarchy of Inference Techniques

Type of Inference

- Threat Analysis
- Situation Assessment
- Behavior/Relationships of Entities
- Identity, Attributes and Location of an Entity
- Existence and Measurable Features of an Entity

High

INFERENCE LEVEL

Low

Applicable Techniques

- Knowledge-Based Techniques
  - Expert Systems
  - Scripts, Frames, Templating
  - Case-Based Reasoning
  - Genetic Algorithms
  - etc.
- Decision-Level Techniques
  - Neural Nets
  - Cluster Algorithms
  - Fuzzy Logic
- Estimation Techniques
  - Bayesian Nets
  - Maximum A Posteriori Probability (e.g. Kalman Filters, Bayesian),
  - Evidential Reasoning
- Signal Processing Techniques

Data Fusion provides ***appropriate*** automation or assistance

Motivation for the DF Model

The Model Provides a Framework for:

- **Understanding Data Fusion Needs**
- **Understanding the Role of Data Fusion**
- **Organizing Data Fusion Development**

FOR

- **Operational Users, Technologists and Managers**

An Evolving Data Fusion Model
Proposed Revisions

The JDL model (1987-91) and the draft revised model (1998)

- Level 0 — Sub-Object Data Association and Estimation: pixel/signal level data association and characterization
- Level 1 — Object Refinement: observation-to-track association, continuous state estimation (e.g. kinematics) and discrete state estimation (e.g. target type and ID) and prediction
- Level 2 — Situation Refinement: object clustering and relational analysis, to include force structure and cross force relations, communications, physical context, etc.
- Level 3 — Impact Assessment Threat Refinement: intent estimation, event prediction, consequence prediction, susceptibility and vulnerability assessment
- Level 4: Process Refinement: adaptive data acquisition and processing (an element of Resource Management)

Summary Data Fusion Technology Assessment (1 of 2)

DATA FUSION LEVEL	SUMMARY OF THE STATE OF THE ART	CURRENT LIMITATIONS	DESIRED NEAR TERM CAPABILITIES
Level 1: Positional, Kinematic, Attribute Estimation	• Relatively mature - numerous techniques for tracking - current research in MHT, JPDA trackers • Object I/D fusion dominated by feature & decision methods - current R&D in ANS and syntactic methods	• Difficulty tracking targets in dense target environment, low SNR, maneuvering targets • Selection of attributes for classification • Selection/use of multiple techniques in concert	• Off-the-shelf software package for robust estimation • Multi-technique approach for object I/D • Methodology & guidelines for algorithm selection • Standard test beds, data sets • Metrics - MOPs/MOEs
Levels 2 and 3: Situation and Threat Assessment	• Relatively immature - heuristic techniques include templating, expert systems - numerous experimental prototypes	• Doctrinal Basis not well-defined • Translation of decision makers needs to fusion req'ts • Automated reasoning techniques • Cognitive models	• Robust techniques to solve subset of situation/threat refinement • Basis for cognitive models
Level 4: Process Refinement	• Very immature - Available technology founded on single sensor experience - immature for multi-sensors - Some MOPs defined (Lvl 1)	• MOE not well-defined • Disconnect between lab/experiment and real world capability • Hybrid architectures challenging	• MOE/MOP Consensus • Metrics baseline • Generic architecture and techniques for multi-sensor control

Summary Data Fusion Technology Assessment (2 of 2)

DATA FUSION FUNCTIONAL AREA	SUMMARY OF THE STATE OF THE ART	CURRENT LIMITATIONS	DESIRED NEAR TERM CAPABILITIES
Human-Computer interface (HCI)	• Numerous tools for rapid prototyping • Current research in display design, crew position layout, workload aspects • Ergonomic *vice* cognitive focus	• Limited HCI research specific to data fusion • Limited cognitive models for focus of attention, stress management, alternative decision styles	• Integrated exploitation of advanced technology (e.g., HDTV, virtual reality, multi-media) • Intelligent Groupware • Multi-person HCI
Data Base Management	• Numerous commercial tools (relational models) • Fourth-generation query languages • Trend toward object-oriented DBMS	• Simultaneous optimization of storage and retrieval • Distributed concurrency • Multi-level security	• Natural language interfaces • S/W based solution to multi-level security • COTS DBMS to handle diverse data (image, text, data, KBS)
Development Environment	• Robust development standards and procedures for conventional systems • Widespread development of application specific prototypes • Single *vs*. multi-sensor models	• Lack of Standard MOPs and test sets • Disjoint test beds and simulation tools • Limited tools/MOE for Level 2,3 fusion	• Robust test-bed for Test and Evaluation • Metrics for MOP/MOE • Fusion Software Library and Clearinghouse • Data Fusion System Engineering methodology

Need for Coordination
State of the Community

- **Everyone Thinks Fusion is Unique to their Community**
  - **Importance is Recognized**
  - **Pervasive nature of Data Fusion is Good/Bad News**
- **Sense of Independent Requirements (Application Independence) by Systems Developers**
- **The Commonality of "Core" Fusion Processes is not Widely Recognized**
- **No Community Process for Evaluating Fusion Operationally or Technically**

Summary

- A Data Fusion Process and core functions have been defined which is operationally beneficial and technically feasible
- In addition to technological growth, the Process requires:
  - Development of an effective infrastructure, and
  - A coordinated systems architecture and engineering environment
- Attention to the infrastructure and environment will enable:
  - More effective leverage of investment in Data Fusion research
  - Better understanding, test and evaluation of data fusion processes
  - More rapid transition of data fusion technologies to fielded systems