DEFENCE DÉFENSE

The Development of Advanced Recognition Concepts for the HALIFAX Class Command and Control System

Bruce McArthur, Sharon McFadden, and Bruce Chalmers

Defence Research and Development Canada

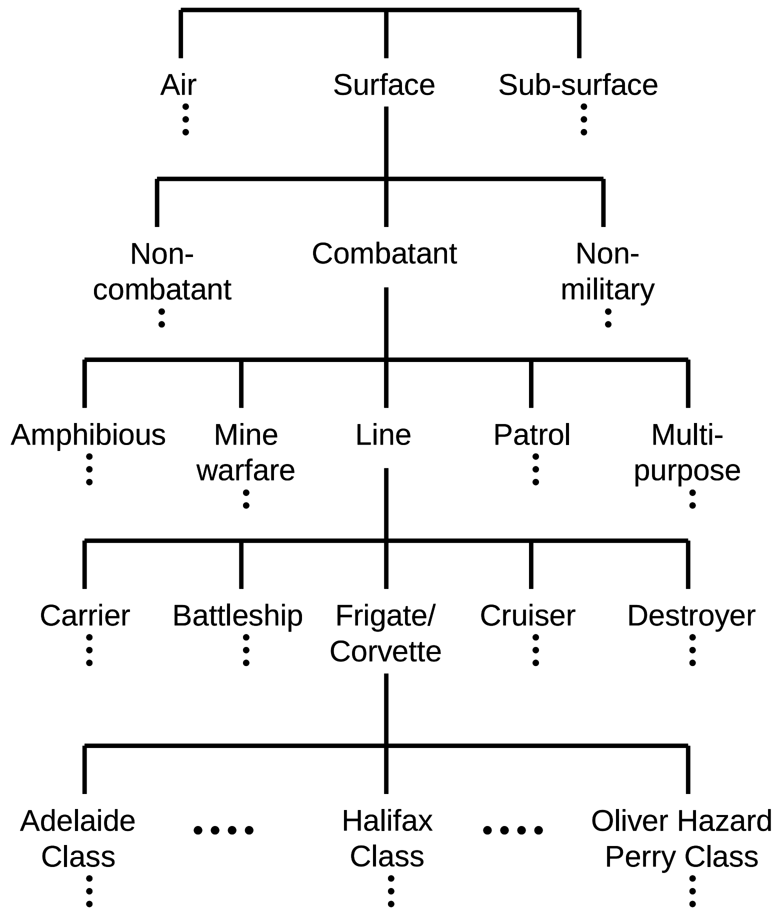
15th ICCRTS, 22-24 June, 2010

Generation of an Integrated Maritime Tactical Picture (MTP)

- The COMDAT Technology Demonstration Project:
  - Demonstration of data fusion for the generation of an integrated AWW Maritime Tactical Picture for the HALIFAX Class
  - Focus on tracking and recognition
  - Leveraged research programs in multi-source data fusion and human factors
- Focal topic of paper:
  - Development of advanced concepts for integrating recognition algorithms into the shipboard environment
- Acknowledgements:
  - Lockheed-Martin Canada (LMC), Humansystems Inc, members of Canadian Forces

Recognition

- Recognition Process: interpretation of data to determine contact characteristics, which are compared against reference data
- Recognition: contact’s identity within a classification hierarchy, with an included confidence level
- MSDF techniques have been widely applied to recognition
  – Application of Dempster-Shafer (D-S) evidential reasoning by DRDC and LMC



Key Challenges

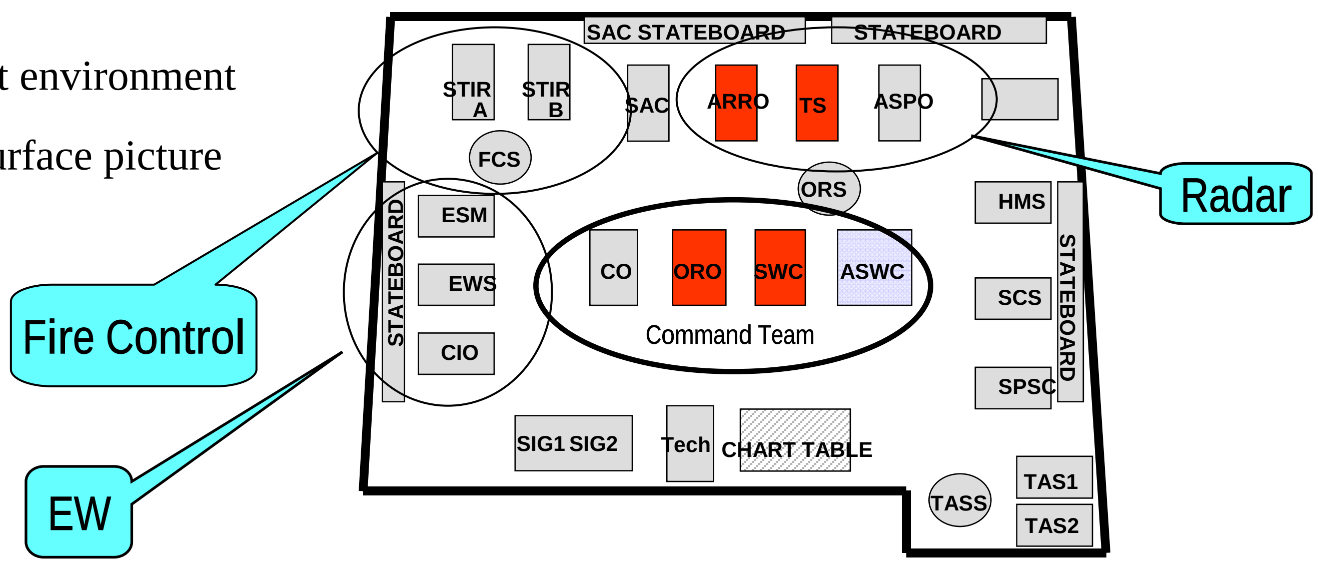
- Understanding how recognition algorithms would enhance decision processes
- Integration of technology with operational work processes
- Requirements to handle incomplete, unreliable, ambiguous, or conflicting input data
- Limited availability of facilities and test subjects to evaluate the technology

Development of Advanced Recognition Concepts

- Models of information flow and decision processes for recognition tasks
- Automated recognition capabilities based on the truncated Dempster-Shafer fusion of attribute data
- Assessment of where data fusion technology might provide the most effective support to operators
- User interface concepts and concept of operations for operator interaction with automated recognition
- Measures and methods for assessing operator and system performance in carrying out recognition tasks

Models of Information Flow and Decision Processes for Recognition Tasks: Data Collection

- Recognized that insertion of advanced technological concepts needs to proceed from an in-depth understanding of the Ops Room work processes to be supported
- SME sessions over 2 days with key members of 2 AWW teams
  - Structured interviews: focus on standard procedures involved in detect-to-recognize process
  - Critical decision method : focus on challenging incidents in non-routine cases
    - Multi-threat environment
    - Complex surface picture



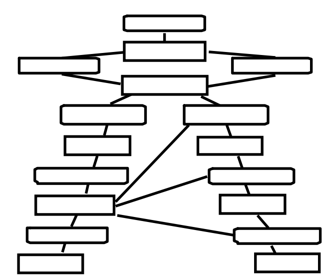
Models of Information Flow and Decision Processes for Recognition Tasks: Analysis

- Descriptive analysis: tabular and graphical representation of the detect-to-recognize process as <u>currently</u> conducted
  - timeline
  - data flows and communications
  - decision points and information used
  - actions
  - information sources and uncertainties
  - strategies

Time →

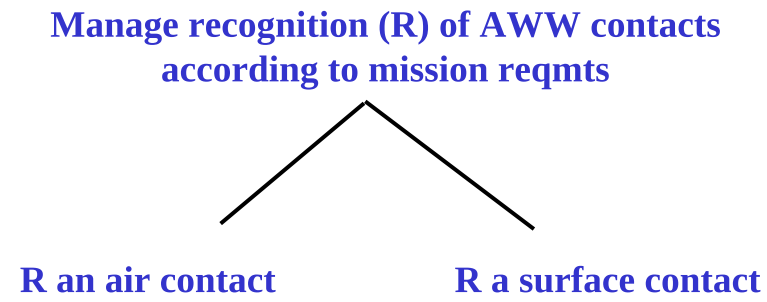
Actions/Decisions				
SWC		Hook track Call resolve, Evaluate inputs from team and close control readout (CCRO) from ow n CCS	Apply ID Crit, assess Assumed Friend	Continue to monitor
ARRO	Hook track Observe CCRO info on track quality, range, course, speed, Mode 3 and C. Observe position relative to air lanes etc in TSA. Report to SWC	Report course, speed, CPA, IFF Modes 3 and C, position relative to air lanes	Amplify contact (ID = UNK, PRI ID = ASS FR), release on Link, maybe make voice report	Continue to monitor

- Formative analysis:
  - broader modeling perspective
  - focus on how recognition <u>could</u> be done
  - based on Cognitive Work Analysis (CWA) decision ladder analysis of critical work functions in recognition process



Models of Information Flow and Decision Processes for Recognition Tasks: Formative Analysis

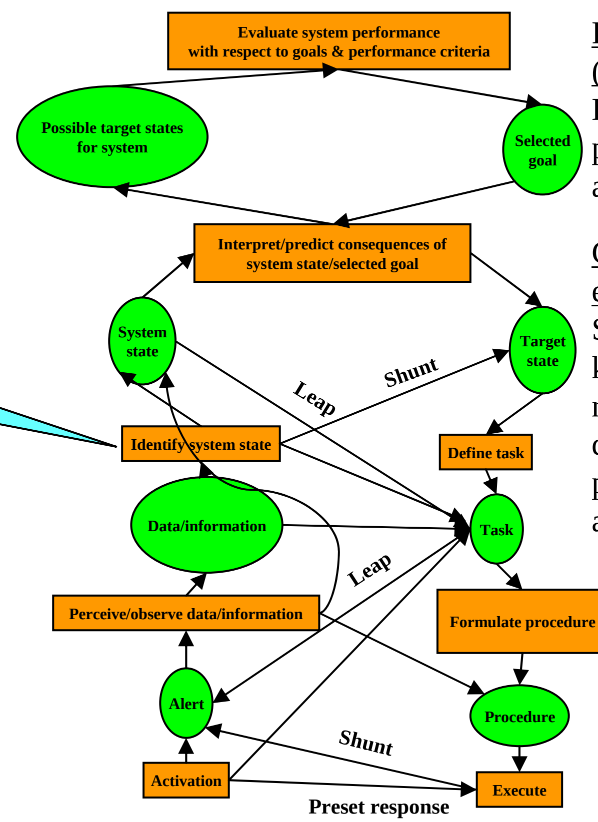
- Decomposed recognition process
  - incorporate a management function
    - prioritize/schedule/time-share processing of individual contacts
  - subordinate recognition functions
    - separate models for air & surface



- Modeled all functions/subfunctions using Decision Ladders

e.g., for the DL to recognize a surface contact:
- visual scan of tactical picture
- note attributes, characteristics, & behavioural patterns of contact
- evaluate info in context of picture, tactical context, possible relationships to other contacts
- weigh reliability of reporting source

etc.



Rectangles (orange): Data/information processing activities

Circles or ellipses (green): States of knowledge resulting from data/information processing activities

- Provided a detailed formative cognitive representation of the recognition process
  - Permits developing an understanding of what generic support could be provided for recognition (e.g., information reqmts)
  - To enable detailed design of tools for supporting recognition, further formative analyses would be needed (e.g., detailed analysis of information processing strategies)

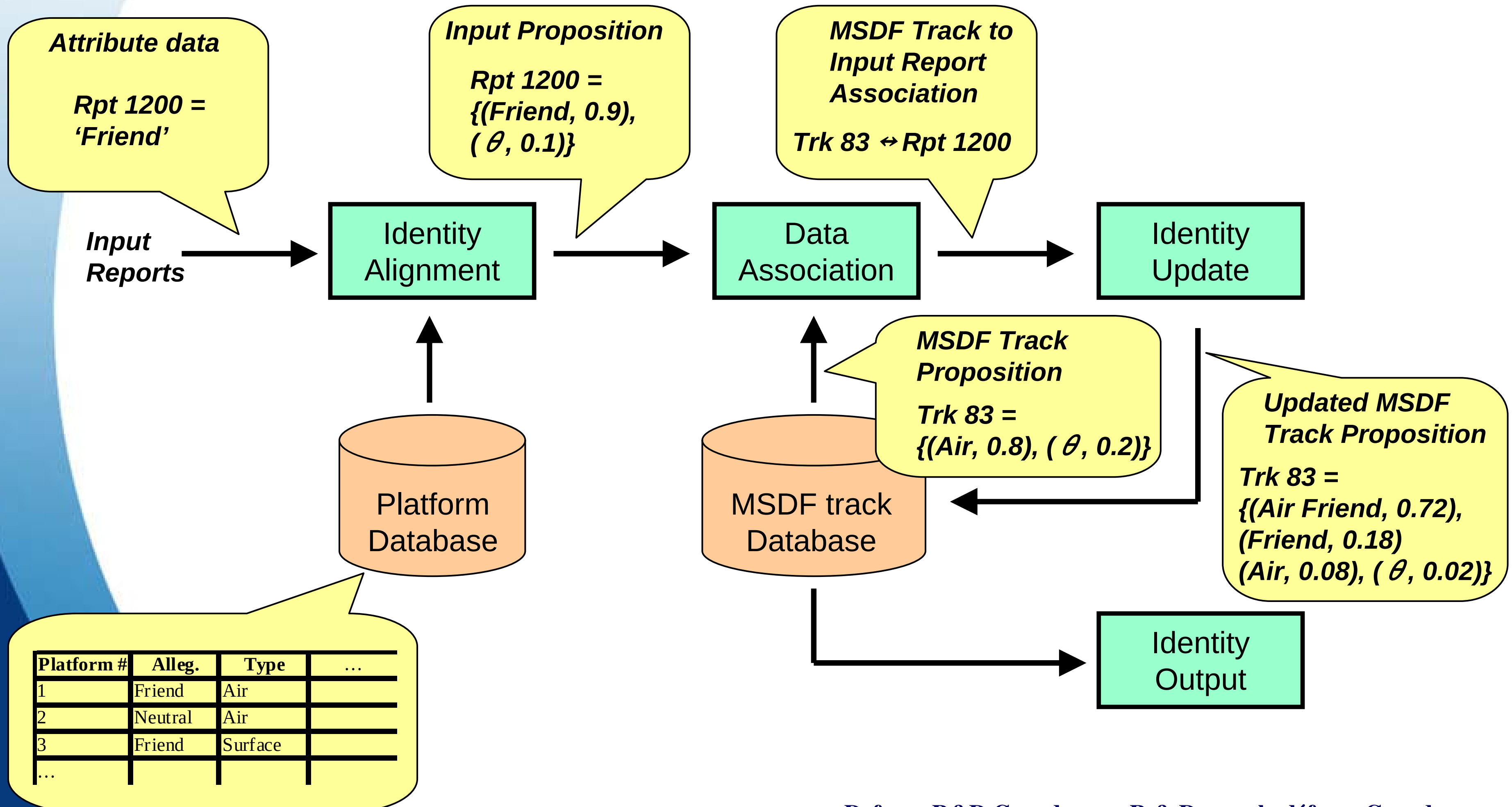
Automated Recognition using Truncated Dempster-Shafer Fusion

- Dempster-Shafer (D-S) evidential reasoning supports the representation and combination of evidence from multiple sources
  - Truncated Dempster-Shafer: computationally efficient variant of D-S
- Using D-S, the recognition domain is defined in terms of:
  - A frame of discernment comprised of air and surface platforms
  - Propositions that correspond to platform subsets
  - A degree of belief assigned to each proposition
- D-S is used to maintain recognition propositions based on attribute data from multiple ownship and remote data sources

Source	Type	Ship Class	Alleg	Country	Emitter	Freq	Speed
Radar	X						
IFF			X				
ESM	X		X		X	X	
Link-11	X		X			X	
GCCS-M	X	X	X	X		X	
MSDF							X

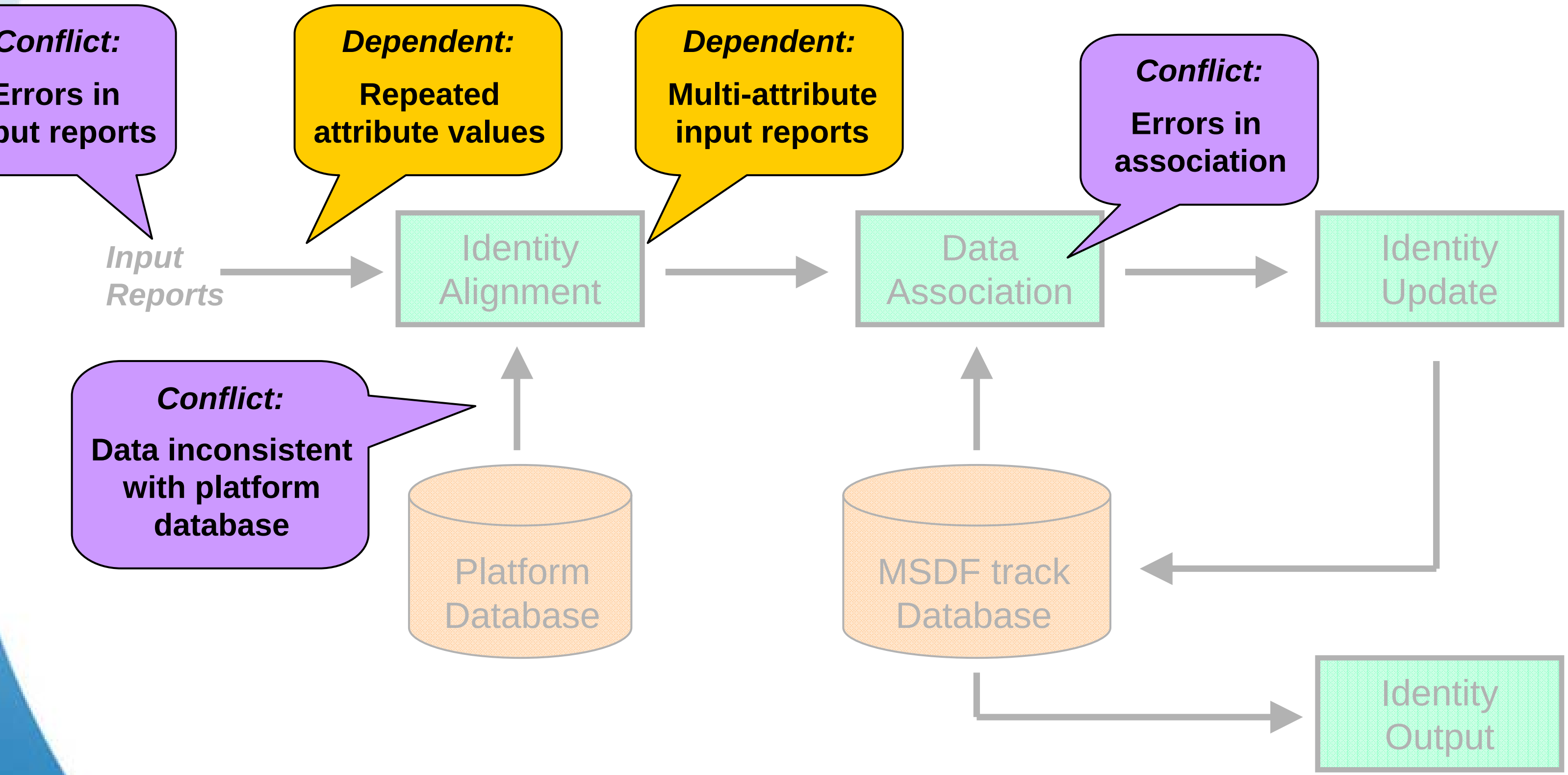
Summary of processed attribute data

Automated Recognition using Dempster-Shafer Fusion of Attribute Data



Platform #	Alleg.	Type	…
1	Friend	Air	
2	Neutral	Air	
3	Friend	Surface	
…			

Impact of Conflicting and Dependent Data on Automated Recognition



Approaches to Handling Conflicting and Dependent Data

- Study of independence assumptions and evidence combination methods
  - Treating dependent data as independent results in over-confidence in resulting beliefs
  - Decision as to which evidence to combine is as important as the method evidence combination
  - Differences between evidence combination methods are significant only when conflict is large
- Use of multiple constraints (kinematic, attribute, track #) to improve data association reliability
- "Intelligent" screening of duplicate attribute measurements

Assessment of the Role of Evidential Reasoning

Evidential reasoning: the process of examining individual and multiple pieces of data to determine the information they collectively provide to make as complete a recognition as possible

– D-S provides one possible algorithmic scheme for evidential reasoning

Used cognitive models of current operator recognition processes to look for evidence of evidential reasoning and situations where D-S functionality could be of benefit:

– helped provide knowledge for the development of a CONOPS for inserting D-S functionality in a useful and useable manner into the Ops Room

As currently implemented in COMDAT, D-S functionality does not have access to a number of important information sources operators use for recognition; e.g.:

– contextual meaning of a contact's movements, point of origin, absence of apparent electronic emissions
– corporate memory of how certain types of contacts have operated historically in the theatre
– intelligence reports or assessments of what to expect
– the meaning of responses or non-responses of contacts when warnings have been issued

Assessment of the Role of Evidential Reasoning (2)

- Identified a limited number of operational situations where D-S functionality could enhance performance; e.g.:
  - in a saturated attack where operators could become overloaded
  - when team is focused on a specific contact and a large number of contacts build in the interim in the wider operational area
- These points argue for inserting D-S functionality to support, not replace, operators' recognition processes

Development of Concept of Operations

1. Determine if the implementation will be evolutionary or revolutionary
   - Organization and personnel unchanged
   - Supporting existing tasks of recognition and ID
2. Resolve the respective roles of the human and the decision support system
   - Commander responsible for assignment of ID
   - Delegation of authority only occurs under specified conditions

Development of Concept of Operations (2)

3. Establish the appropriate level of support for human decisions
   - High automation level takes away decision making responsibility
   - If too low, unlikely to see substantive benefit from automation
4. Integrate decision support functionality into the operational context
   - Position MSDF as a collaborator with rather than replacement for human operator

OMI Concepts - Operator as Input

- Based on outcome of concept of operations and evidential reasoning analysis
  - Positioned MSDF as collaborator
  - Allowed MSDF to consider “non-sensor” information
- Means:
  - Operator could provide alternative recognition probabilities for specific tracks
  - MSDF processed sensor only and sensor + operator input in parallel
    - Operator could test “what-if” hypotheses

Operator as Input - example

▼ Single Contact Propositions Page

AA	DA	SA	PC	EW	Track	Brg	Rng	Crs	Spd	Lgth	Duration
					2236	▶ 153	▼ 23	▶ 311	▼ 12		00:03:00

Authorized Force Recognition State		
Poss High	Warship, element of SAG 1A	Unassociated ESM, speed, in intel area

Propositions	Organic MSDF	Operator Input
ID	Suspect	
⊞ Category	▲ Poss High 72% Merchant ▷ Spd 12	**Cert 95% Warship** ▷ ISAR from MPA (SAC), Spd 12
⊟ Type	▼ Poss Low 44% Container ▷ Spd 12	▲ Poss Low 23% Frigate ▷ Spd 12
		▼ Poss Low 15% Destroyer ▷ Spd 12
		▲ Poss Low 11% FPB ▷ Spd 12
⊞ Class		▼ Poss Low 11% Godavari ▷ Spd 12
Name		
⊞ Flag		India

Assessing Performance: Development of Operator Measures of Performance

- Based on goals from cognitive task analysis
  - E.g., Build and maintain awareness of air picture
- For each goal developed
  - Criteria:
    - acquire and maintain awareness of significant issues
    - detect pertinent changes in air picture
    - identify hostile contacts
  - Measures of performance(MOPs):
    - percent of current air contacts processed
    - response time to identify hostile contact
  - Methods for assessing measures:
    - embedded probes
    - SME review of real time or video of the scenario execution

Assessment of Human-Machine Performance

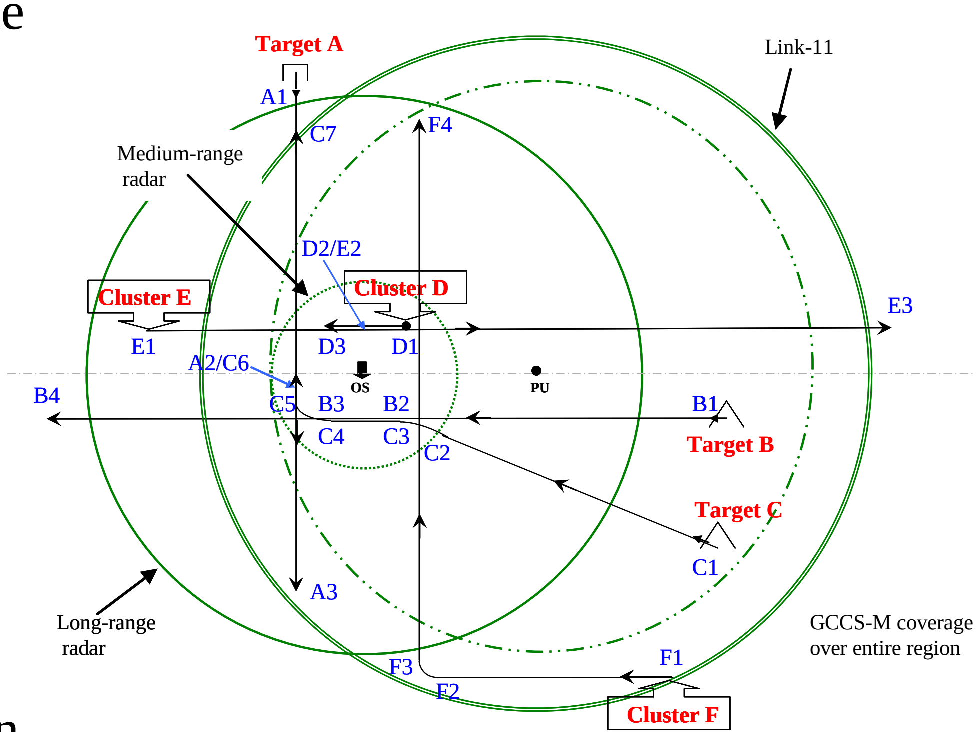
- Issues:
  - Needed access to experienced operations room teams in realistic environment
  - Limited availability
- Solution:
  - Analysed archived training runs
    - Wide range of scenarios
    - Carried out by experienced naval personnel
  - Possible to collected data on 64 MOPs

Summary of Baseline Study

- Analysed multiple anti-air and anti-surface warfare scenarios
- Collected means and standard deviations on 27 anti-air and 17 anti-surface warfare MOPs
- Fourteen errors:
  – Situation awareness/attention: 3
  – Recognition: 5
  – Procedure: 6
- MSDF could have mitigated 13 of these

Assessing Performance: Shore-Based Test and Evaluation of Automated Recognition

- Test environment based on the Combat System Test Centre (CSTC) mini-system
- Six scenarios developed to test:
  - Recognition based on multi-source fusion of attribute data
  - Impact of conflicting attribute data on recognition performance
  - Impact of attribute data on association



Assessing Performance: System Measures of Performance for Automated Recognition

- System MOPs for recognition categorized by: accuracy, completeness, clarity, timeliness
- Performance test carried out using three MOPs related to accuracy and completeness
  - Category: recognized accurately
  - Sub-category: generally correct once a recognition was declared but more easily affected by data association
- Scenario design and test procedures used to discriminate the effects of tracking and data association on recognition performance

Concluding Remarks

- Important outcomes of COMDAT:
  - Detailed understanding of operators’ recognition and decision processes
  - Development of MOPs and assessment methods
  - Extensions to existing algorithms in order to process realistic data
- Lessons learned:
  - Importance of conducting cognitive analyses early in the project
  - Requirement for realistic environments in which to integrate new technologies and evaluate system concepts

DEFENCE R&D DÉFENSE