Australian Government
Department of Defence
Defence Science and
Technology Organisation

On The Changing Nature of Air Combat: Real and Simulated

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Aerospace Operations Research

Joint & Operations Analysis Division

Dr Clint Heinze

Counsellor Defence Science & Technology

Australian Defence Staff

Australian High Commission – London

1980 Operational Research Group
1983 Combat Effectiveness Group
1988 Studies Group
1991 Studies and Simulation Group
1998 Air Combat Assessment
2001 Aerospace Operational Analysis
2007 Aerospace Capability Assessment
2013 Simulation Experimentation and Wargaming


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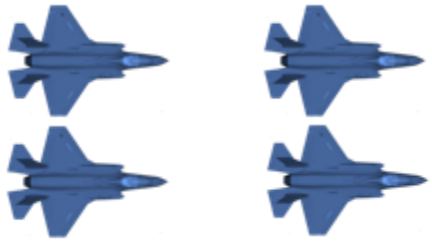
DARPA
UCAV
BOEING PHANTOM WORKS

Air Combat Constructive Simulation

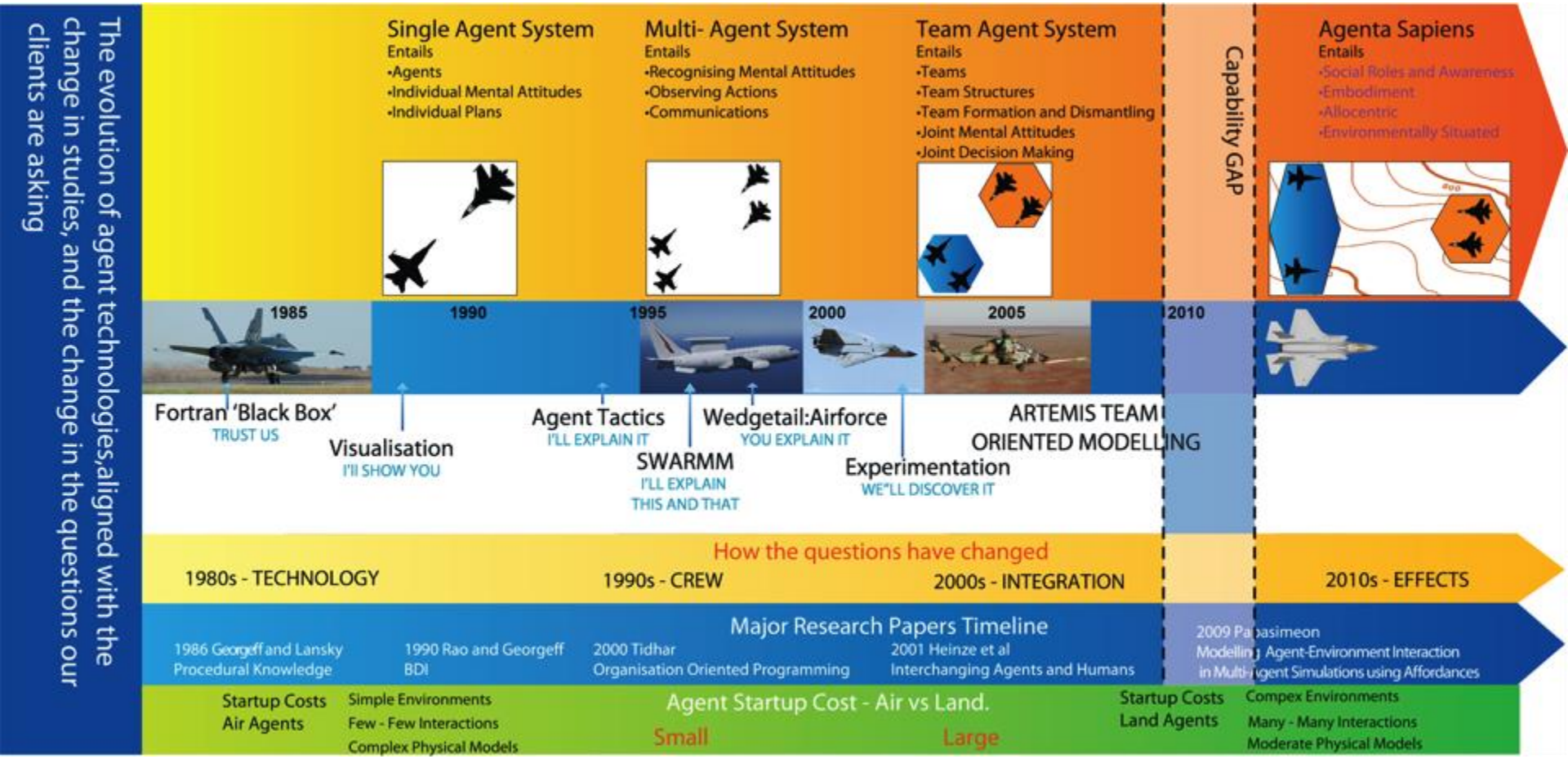
- Operational Analysis in support of:
  - TTPs & CONOPS evaluation and assessment
  - Acquisitions
  - System upgrades
- Monte-Carlo Simulation
- Statistical Measures of Effectiveness
  - Lethality, Survivability, Exchange Ratios etc
- Very large parameter space



History

PACAUS, SWARMM, dGAME, Battlemodel, ARTEMIS

ACE



Five Generations of Air Combat Simulations

PAC**AUS**

SWARMM

BattleModel

ARTEMIS

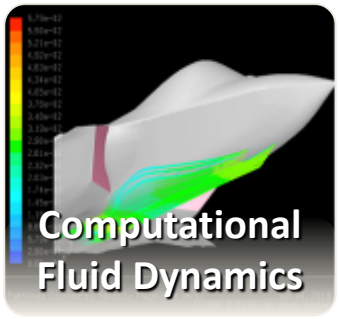
ACE
AIR COMBAT ENVIRONMENT

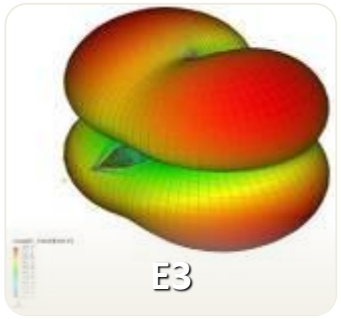
Air Combat Simulation Deployed Applications

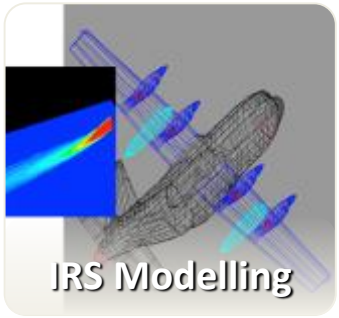
PACAUS		Within Visual Range (WVR) Air Combat Constructive Simulation. FORTRAN 77. 100,000+ LOC.
SWARMM		Beyond Visual Range (BVR) Air Combat Constructive Simulation. FORTRAN 77 + dMARS Intelligent BDI Agents (AAII). Split between physical models and reasoning models.
dGAME		Distributed, component based architecture with intelligent wrapping. Designed for automated integration of legacy components. dMARS, C++, CORBA.
BattleModel		Object oriented simulation framework written in C++ (and dMARS). Designed for integrating legacy components for AEW&C acquisition. Brought about changes in software engineering culture.
ARTEMIS		BattleModel variant for future air combat analysis (F-35A JSF). Hybrid object and agent oriented architecture C++ and JACK (Java). First introduction of team oriented agent programming constructs.

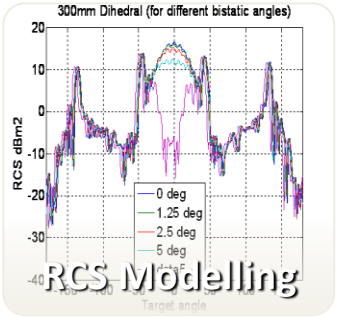
Fighter Computational Modelling

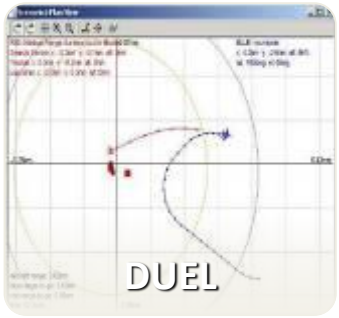
Computational Models of Fighter Systems

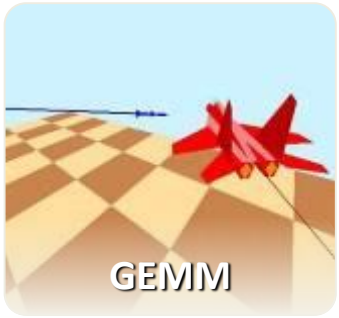


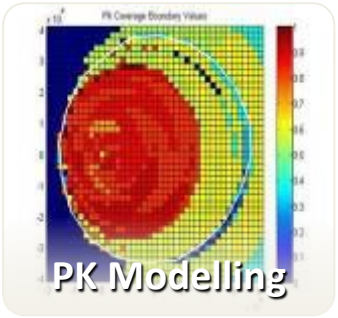


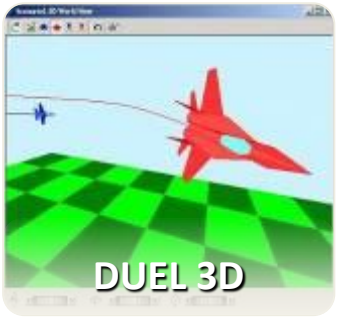








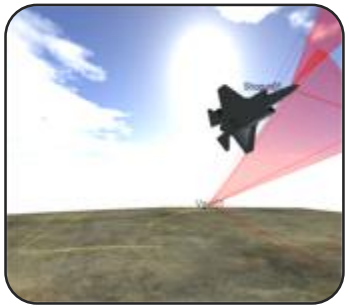


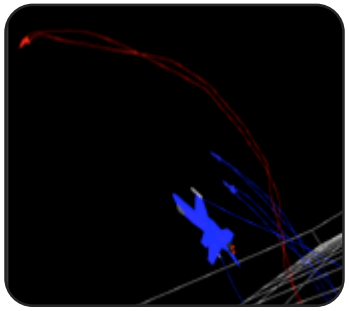


Simulation Supporting Air Combat Acquisitions

Complex Multi-Billion $AUD Acquisitions

Supported by Operations Research Simulation



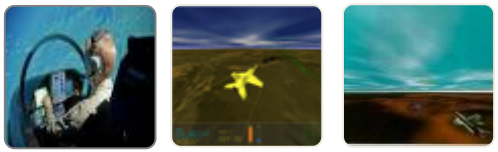


Integrating Components Sourced Across DSTO

DSTO SME

Built on Foundation of 20 Year R&D Program

DSTO Analysts
Air Combat
Domain Knowledge



Software Engineering of
Air Combat Simulation
Technology

Research into Autonomous & Intelligent Agents and Artificial Intelligence for modelling fighter pilot decision making extending back over 20 years.

Modelling Tactics and Situational Awareness

Observe (situation awareness)
Orient (situation assessment)
Decide (course of action)
Act (tactics)

Beliefs
Desires
Intentions → plans

dMARS

JACK AUTONOMOUS SOFTWARE

CoJACK

Beliefs, Desires and Intentions (BDI) Model

- Internal mental attitudes of a rational BDI agent (or an agent's mental state)

- **Beliefs:** what the pilot believes about the world, itself and other agents (informational)
- **Desires:** What the agents what to achieve (motivational)
- **Intentions:** how the agents tries to achieves its desires (deliberational)

Rational Agency and BDI

- Folk Psychology – Daniel Dennet
- Rational Agency – Michael Bratman
- Formal Logical Framework – Rao and Georgeff
- Specific BDI Programming Languages
  - PRS, dMARS, JACK, Co-JACK, JAM, GORITE etc.

Research

PhD Studies

THE UNIVERSITY OF MELBOURNE

TODD MANSELL Planning Under Uncertainty	GIL TIDHAR Organisation Oriented Systems: Theory and Practice	DAVID MORELY Semantics of Actions, Agents and Environments	DAVID KINNY Fundamentals of Agent Computation Theory: Semantics	CLINT HEINZE Modelling Intention Recognition for Intelligent Agent Systems	
MICHAEL PAPASIMEON Modelling Agent-Environment Interactions in Multi-Agent Simulations with Affordances	SUSANNAH SOON Multi-Agent Coordination: A Graph Based Approach to Intention Recognition	RAYMOND SO Situation Awareness in Software Agents: Theory & Practice	DON PERUGINI Agents for Logistics: a Provisional Agreement Approach	SAMIN KARIM Acquiring Plans Within Resource Bounded Agents	EMMA NORLING Modelling Human Behaviour with BDI Agents

Programming Languages

AOS Autonomous Decision-Making Software

JACK AUTONOMOUS SOFTWARE

dMARS

CoJACK

PRS
AgentSpeak
dMARS-R
dMARS-C2
SimpleTeams
JACKTeams
OKRA

Methods and Models

OODA
Cognitive Work Analysis
JACK-UML extensions
"The Four-Box Model"
AOSE
Intention Oriented Analysis and Design
Naturalistic Decision Making
Recognition Primed Decisions

Simulation Frameworks

KESEM INTERNATIONAL

CAE

AVT Advanced VTOL Technologies

Integration

External Engagement 2013

BRAWLER

Brawler Team
USAF/A9 @ The Pentagon

Air Combat Constructive Simulation
Analysis Methodology
Electronic Warfare Modelling

Air Operations Simulation Centre

NFS
NACC FLIGHT SIMULATOR

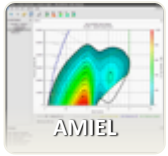
Integrated OR Experimentation
Analytics
AESA Radar Modelling
EW Modelling
General Computational Modelling

Statistical Analysis of Simulation Data

THE UNIVERSITY OF MELBOURNE

Statistical Consulting Centre
Department of Mathematics & Statistics

Flight Systems Branch



POC: Kevin McDonald

Weapon Systems & CM

WAMUG
POC: Russell Connell

Next-Gen AESA Model

NSID: Tim Coombs
John Whitrow
AD: Maria Vukovic
Mike Spataro
JOAD: Josef Zuk
Lyndon Benke

Vacation Students

Data Mining — RMIT UNIVERSITY

Air Combat Simulation Interaction & Visualisation — UNSW

GPU Sensor Modelling — RMIT UNIVERSITY

Example: Air Combat Analytical Capability

Client Program Analysis

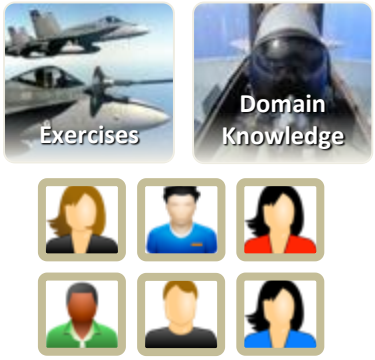
S&T Capability Development

ACE AIR COMBAT ENVIRONMENT
MFS MANNED FLIGHT SIMULATION

In-House M&S Capability

Australian Tools

External Tools

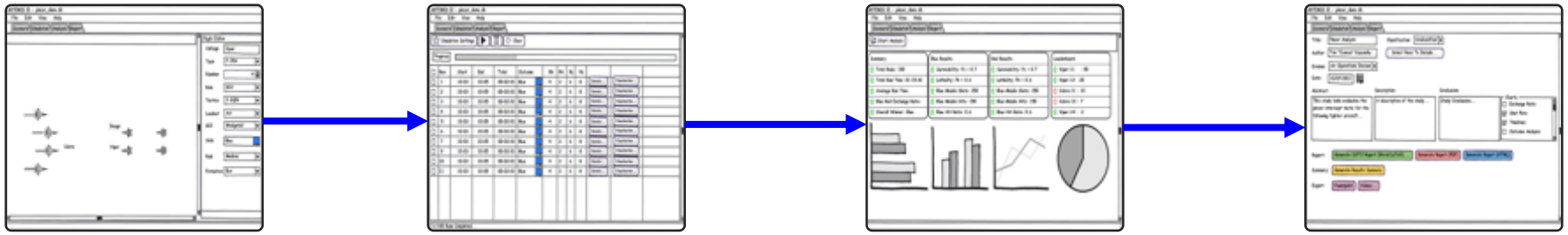


Staff Training & Subject Matter Experts

Enabling Research

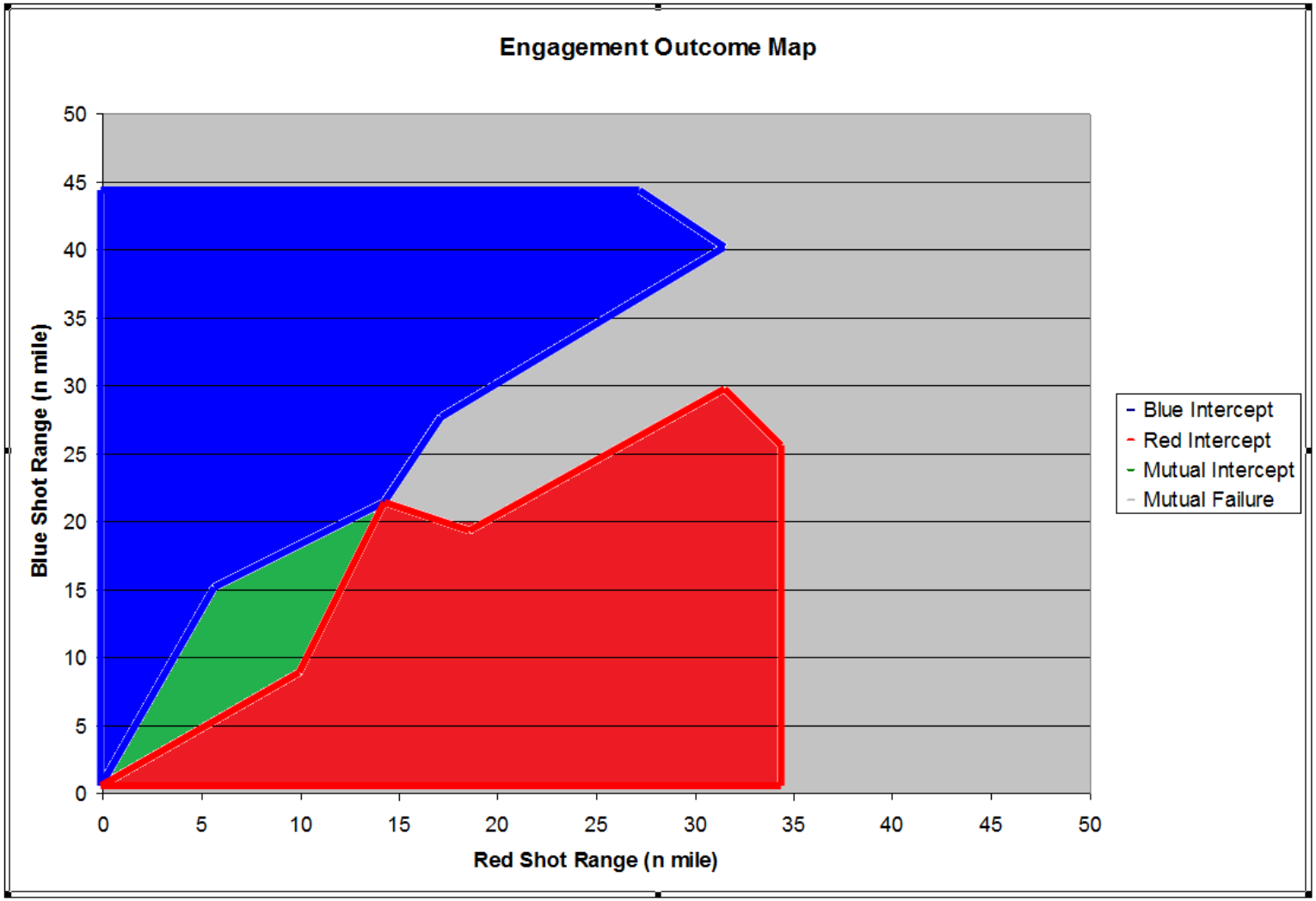
Analyst Workflow

- The goal is to support the analyst across the entire air combat study workflow…

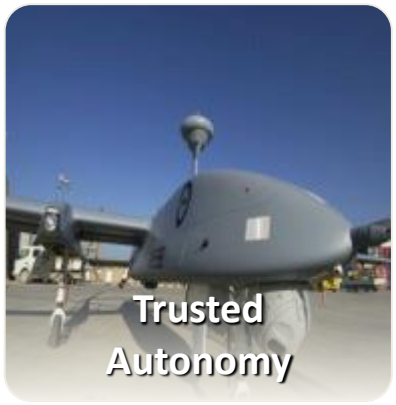


Scenario Setup → **Simulation Execution** → **Analysis** → **Reporting**

Sample Chart: Engagement Outcome Map



Future Challenges in Modelling & Simulation



Human In The Loop Air Combat Simulation

Autonomy and Aerospace Operations Research