

## C2 Algorithms and Joint Modelling in the COMAND Model

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### **ABSTRACT**

*In 1996 the UK MoD highlighted the lack of analytical methods to assess issues relating to the balance of investment in ICS (Information and Communications Systems) and ISTAR (Intelligence Surveillance Target Acquisition and Reconnaissance) systems. A method using two high-level combat models (CLARION, a land model, and COMAND, a maritime and air model) has been developed to assess the impact of these systems on campaign outcome. This paper presents a discussion of some of the key command, control, communications and intelligence (C3I) functionality in one of these models, COMAND, and describes how it links with CLARION to create a joint modelling environment.*

**Key Words:** *Simulation, Research, C3I, Joint, Validation.*

### **1.0 BACKGROUND**

In July 1996, the UK Ministry of Defence (MoD) highlighted the lack of analytical methods to assess issues relating to the balance of investment in ICS (Information and Communications Systems) and ISTAR (Intelligence Surveillance Target Acquisition and Reconnaissance) systems. CDA (Centre for Defence Analysis), now Dstl (Defence Science and Technology Laboratory) Analysis, were asked to develop a methodology to address this. The use of campaign models to assess the achievement of campaign aims and hence advise MoD on balance of investment issues concerning weapons and platforms has been carried out for many years. The challenge was to develop a methodology that would allow ICS and ISTAR systems within the joint battlespace to be judged using these same high level measures of effectiveness.

A methodology was developed utilising the strengths of the then recently developed land/air combat model CLARION (Combined Land/Air Representation of Integrated OperatioNs). In order to consider COMAND in context, it is useful to contrast it with CLARION. CLARION provided a representation of command and control that was well in advance of previously available theatre-level models and had been designed particularly with a view to modelling manoeuvre warfare. However, in order to develop a method that would be able to examine systems across the joint domain, a campaign model that represented the maritime domain and provided a more detailed representation of the air domain was required. Therefore, Dstl Analysis have developed a new model called COMAND (C<sup>3</sup> Orientated Model of Air and Naval Domains) to meet this demand.

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## **C2 Algorithms and Joint Modelling in the COMAND Model**

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The essential features of COMAND, then, are its C3I functionality and its ability to model the contribution of the maritime and air components to the joint campaign. This paper concentrates on the COMAND model, the key aspects of its C<sup>3</sup> (Command, Control and Communications) and ISTAR functionality and its use together with CLARION to provide a joint modelling environment; it does not, however, discuss the complete methodology for assessing ICS and ISTAR.

### **2.0 CLARION AND COMAND OVERVIEW**

CLARION is a two-sided, time-stepped theatre-level representation of land/air combat. CLARION is capable of being run in both a deterministic and stochastic mode; the stochastic mode is a recent development and introduces random elements into direct fire, sensing and some decision thresholds. CLARION represents the combat and surveillance capability of direct fire, artillery and reconnaissance units, their headquarters, attack helicopters and aircraft. Although CLARION may be used to model a fuller air campaign including defensive and offensive counter air and air interdiction, functionality is most comprehensive on the representation of the land battle.

COMAND is a three-sided<sup>1</sup>, stochastic<sup>2</sup>, event-driven theatre-level representation of maritime and air contributions to a joint campaign. COMAND has a simple representation of the land battle that allows the representation of joint operations. COMAND's third side allows the representation of neutral aircraft and ships. COMAND represents ships (including aircraft carriers), submarines, aircraft, helicopters, satellites, airbases, ports, strategic targets, land-based missile sites, radar sites and the land battle. It represents the weapons and sensors of these entities and the interactions between entities where appropriate.

Both models have a 'high level' representation, meaning that the scope is broad and that where possible simple algorithms are derived from the result of more detailed lower level modelling.

Both models are PC-based and capable of running within a Microsoft NT Windows environment. Both have been designed with the intention of providing the analyst with an easy-to-use tool capable of giving results in time scales and costs acceptable to customers<sup>3</sup>.

### **3.0 THE COMMAND HIERARCHY AND COMMUNICATIONS**

COMAND has been developed with a flexible command hierarchy that allows it to model any command structure or doctrine. It has a Joint Force Commander (JFC) who is in charge of the whole campaign with subordinate domain component commanders.

The maritime hierarchy devolves below the Maritime Component Commander (MCC) to task group commanders who may be in charge of anything from a carrier battle-group to a single submarine.

Most of the air C2 is handled within the Combined Air Operations Centre (CAOC), at a relatively high level. This is represented in COMAND by a range of commanders each of whom takes on the role of one of the cells within the CAOC, for example there is a Defensive Counter Air (DCA) commander, a Suppression of Enemy Air Defences (SEAD) commander, etc.

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<sup>1</sup> NATO Code of Best Practice Section 8-B-4 [1].

<sup>2</sup> NATO Code of Best Practice Section 8-B-3 [1].

<sup>3</sup> NATO Code of Best Practice Section 8-B-7 [1].

Land-based assets are handled in a similar way to maritime assets; a commander may be in charge of a group of systems. For example there may be one commander in charge of a side's air defence SAM sites, another in charge of its early warning radars, etc.

Although COMAND is not a communications model, it does represent the flow of key information types. These are listed below:

- a) Orders and status reports. These flow down and up, respectively, the command hierarchy.
- b) Support requests. Each commander can have a number of other commanders from whom he may request support. This may not necessarily follow the command hierarchy. For example, if the commander of the bombing campaign feels that a particular target may be too dangerous to send manned aircraft against he may directly ask a submarine to fire a cruise missile.
- c) Intelligence. The flow of intelligence takes the form of all-informed networks. Whenever intelligence enters a network it is passed to everybody else on that network, although communications delays may mean that not every commander receives the information at the same time.

### 4.0 MISSIONS AND COMMAND AND CONTROL

Missions are the building blocks from which scenarios are created. They are used equally in all domains and are a task that a commander may be assigned to carry out. Missions fall into the following broad categories:

- a) Attack;
- b) Escort;
- c) Patrol.

The mission-based structure is the key to all of COMAND's representation of command and control<sup>4</sup>. Using this mission-based structure it is possible to represent the 'deliberate' planning of senior commanders at the higher levels of the command hierarchy. This is the type of planning where a commander has enough time to consider the situation in detail and arrive at a course of action, which will look out over a number of days. This course of action takes the form of a plan and contains a series of missions, which is passed down the command hierarchy.

The mission-based structure also allows the representation of bottom-up 'rapid' planning, where field commanders must make quick, time-pressured, decisions about their immediate environment and the threat. Rapid planning allows a commander to elect not to attack an enemy target if it is too strong and instead request support from another commander. At the moment, rapid planning is only represented in the maritime domain in COMAND.

### 5.0 AIR C2

As previously mentioned most of the air C2 occurs at the CAOC. Here the Air Component Commander (ACC) monitors the status of each domain and assesses the allocation of aircraft to roles. For example, if the maritime campaign is progressing well, but the land battle is not, he may decide to switch effort from maritime attack roles to close air support (CAS).

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<sup>4</sup> NATO Code of Best Practice Section 8-B-1 [1].

## **C2 Algorithms and Joint Modelling in the COMAND Model**

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The status of each domain is measured using Campaign State Vectors (CSVs). These are specific to each domain, but typically take the form of the ratio of the enemy's capability to friendly capability. For example, the maritime CSV is the ratio of each side's anti-surface warfare (ASuW) and anti-submarine warfare (ASW) capability.

During the process of planning each day's sorties the ACC conducts a fast, deterministic, run-through of each mission in order to assess its support requirements. During this process, if losses for a sortie exceed a user-specified level even after adding as many support aircraft as he can then that sortie is removed from the Air Tasking Order (ATO) and the released effort spread amongst the other missions, if possible. At this stage the ACC may then request support from other commanders holding land-attack cruise missiles.

### **6.0 RAPID PLANNING**

Each commander maintains a track table, which endows him with a degree of situational awareness. This track table is built up using the group's own organic sensors (radars and sonars onboard ships, the dipping sonars of helicopter screens, etc.) and also via any intelligence networks the commander has access to. Through the intelligence networks a commander may have access to the sensors of maritime patrol aircraft, other task groups, airborne early warning (AEW) aircraft and satellites.

Each track contains information such as platform type, bearing, speed, etc. and may be built up from a number of different sensors, each one providing a different piece of information. Perfect track fusion is assumed in compiling the information. Each track is time-stamped and if it is not updated after a certain length of time then it is discarded.

In COMAND, the key to rapid planning is the commander's threat assessment, which is carried out based on the contents of his track table. Delays in receiving information on those tracks may lead to a commander making inappropriate decisions. This is one of the key impacts of communications on the model.

A commander may be in one of two postures, either offensive or defensive, which are defined according to the particular mission he is carrying out. For example, a fast patrol boat (FPB) may be set-up to have an offensive posture. This limits the commander's perception of what a threat may be to only those tracks that he believes may shortly come within weapon range of him. This allows him to ignore tracks and carry on with his assigned mission unless he believes they will be able to interfere. However, a carrier battlegroup may have a defensive posture. This allows the group to dominate a large area considering everything that moves to be a threat and to be dealt with appropriately.

Once a track becomes a threat, an assessment is carried out in order for the commander to arrive at a course of action. The threat assessment process involves taking the perceived capability of the threat and comparing it with his own. If the assessment is unfavourable then the commander may seek to evade the threat and request support from other commanders, as defined by the user, to prosecute the contact; if it is favourable then the commander may elect to attack the threat himself.

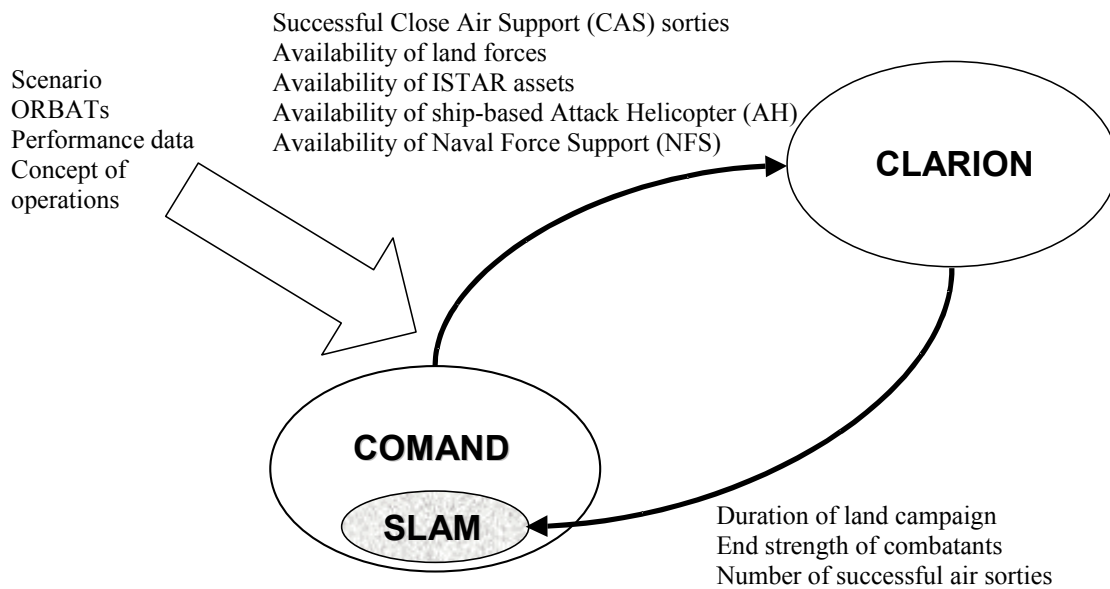
### **7.0 JOINT MODELLING**

Dstl Analysis does not currently have a single combat model capable of allowing a comprehensive examination of joint operations. Therefore, it has been a requirement from the outset of the development of

COMAND that it should have the capability to interface with CLARION, thus allowing capabilities and systems across the joint domain to be assessed in a robust, efficient and balanced way<sup>5</sup>.

Such an interface may be achieved manually in the current versions of the models by utilising COMAND’s simple aggregated representation of the land battle (called SLAM (Simple Land Analysis Model)), based on historical analysis<sup>6</sup> algorithms. These algorithms were empirically derived by examining the key factors that have influenced the outcome of past conflicts. Within COMAND this provides a dynamic representation of the land battle that allows the JFC and the Land Component Commander (LCC) the opportunity to monitor the progress of the land battle and change their campaign plans appropriately. It also enables assets such as aircraft and naval gunfire to influence the land battle.

If the models were to be used together, relevant data such as that shown in Figure 1, below, would need to be passed between them. COMAND would provide the numbers of sorties flown and availability of assets that could influence the land battle. CLARION would then be run to provide key outputs in order to calibrate SLAM within COMAND. This process may need to be carried out iteratively until stability within the models is achieved.



**Figure 1: Manual Linkage between COMAND and CLARION for Joint Modelling.**

In the future it is hoped that COMAND may be linked to CLARION in ‘real time’ via High Level Architecture (HLA). This will allow the models to trade key communications between commanders and interactions between domains.

<sup>5</sup> NATO Code of Best Practice Section 8-B-2 [1].

<sup>6</sup> Historical Analysis is the extraction of quantitative information from past conflicts. It is of most value in identifying and quantifying factors that reflect human behaviour and capabilities in battle, since these are difficult to pin down by other means.

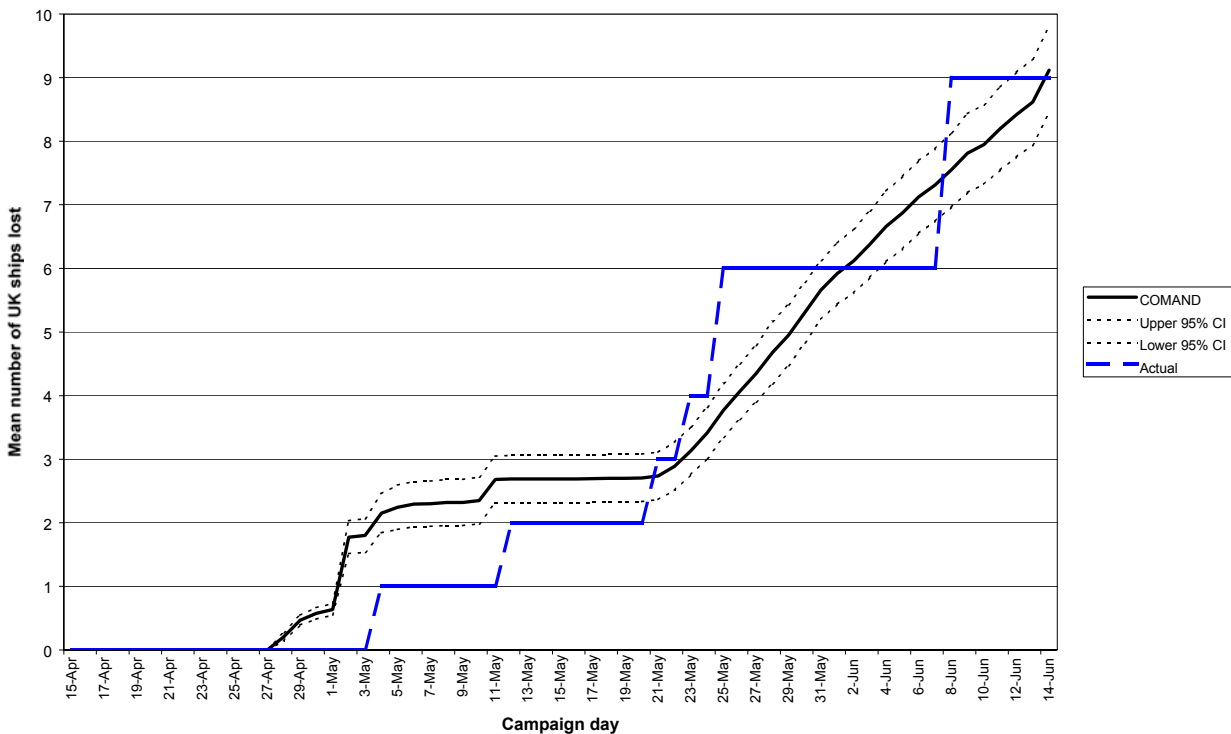
**8.0 VALIDATION EXERCISES**

COMAND has been extensively validated; three strands were used in the validation process, listed below<sup>7</sup>. This section, however, will only give a brief overview of the first.

- a) Historical comparison – 1982 Falkland Islands conflict;
- b) Comparison against future conflicts using current Dstl campaign models – the Maritime Campaign Model (MCP) and the Theatre Analysis Model for Air-Related Issues (TAMARI);
- c) Data review.

The three strands were selected to allow the programme to cover the whole scope of validation. Past conflicts, which enabled the non-technology aspects that can affect a campaign to be investigated. Future conflicts, which the model will be used to represent in practice. Data review, to ensure that data are as up-to-date as possible and in the correct form for input to the model.

The 1982 Falkland Islands conflict was selected because it is one of the few instances of modern naval combat operations. Figure 2 illustrates one of the key measures used in the validation exercise: the number of UK ships destroyed in the conflict over time. The dashed line is the number of ships lost in reality, the solid line is the mean number of ships lost from COMAND and the thin dotted lines are the 95% confidence intervals.



**Figure 2: Comparison of UK Ship Losses in COMAND and Reality.**

<sup>7</sup> NATO Code of Best Practice Section 8-B-5 [1].

Figure 2 shows that COMAND was able to produce similar results to those from the actual campaign. The only significant data change was to the Argentinean sortie rate, which was degraded to account for the poor weather predominating for much of the campaign. This is why, from 21<sup>st</sup> May, UK ship losses in COMAND increase smoothly, whereas in the real campaign there are large steps. System performance data were based on analysis of the actual campaign conducted at the time, so if 3 out of 10 bombs that were dropped actually hit, a probability of hit of 0.3 was used in COMAND.

The key part of the curve occurs from 21<sup>st</sup> May, when the Task Force entered San Carlos water, and UK ship losses begin increasing steadily. This is because the Task Force could be easily detected by the Argentinean sensors based on the Falkland Islands and allowed the Argentineans to generate sorties against those ships. In previous models, this behaviour would have been scripted.

This validation exercise demonstrated that COMAND was capable of representing an expeditionary maritime/air campaign providing significant confidence for study use. In addition, using a historical scenario highlighted areas that were of importance to the battle but not modelled explicitly, such as, in the example above, weather.

## 9.0 SUMMARY

COMAND allows the analyst to examine the merits of different deployments, force structures and system mixes within a variety of scenarios in the joint domain, especially allowing ICS and ISTAR systems to be assessed using the same traditional high level measures of effectiveness as platforms and weapons.

The C3I functionality within the models provides the opportunity to show the benefits of investing in better ICS and ISTAR systems. Decision making entities that receive better and more timely information are able to make better-informed decisions. Consequently, entities may then act in a way they believe to be of most advantage, which may mean evading rather than engaging a hostile threat of greater capability. This represents a significant step forward from the attrition-based models previously used.

Although COMAND with its simple land representation can be termed a 'joint' model, it does not represent the land battle in sufficient detail to offer a balanced assessment across the joint arena. However, linked manually or via a network, COMAND and CLARION are able to achieve this in a robust and efficient manner.

Following an extensive validation a high degree of confidence exists in COMAND's capabilities, both as a tool for assessing the impact of ICS and ISTAR on campaign outcome and in its role as a campaign analysis tool.

COMAND is one of a new wave of models that reflects the changing nature of conflict, being driven by command and control and the use of information to drive successful prosecution of a campaign.

## 10.0 REFERENCES

- [1] NATO Code of Best Practice on the Assessment of Command and Control.
- [2] Moffat, 2002.

### 11.0 LIST OF ACRONYMS

ACC	Air Component Commander
AEW	Airborne Early Warning
AH	Attack Helicopter
ASuW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
ATO	Air Tasking Order
C2	Command and Control
C3	Command, Control and Communications
C3I	Command, Control, Communications and Intelligence
CAOC	Combined Air Operations Centre
CAS	Close Air Support
CDA	Centre for Defence Analysis
CLARION	Combined Land/Air Representation of Integrated OperatioNs
COMAND	C3 Orientated Model of Air and Naval Domains
CSV	Campaign State Vector
DCA	Defensive Counter Air
DERA	Defence Evaluation and Research Agency
Dstl	Defence Science and Technology Laboratory
FPB	Fast Patrol Boat
HLA	High Level Architecture
ICS	Information Communication Services
ISTAR	Intelligence, Surveillance, Target Acquisition and Reconnaissance
JFC	Joint Force Commander
LCC	Land Component Commander
MCC	Maritime Component Commander
MoD	Ministry of Defence
NFS	Naval Fire Support
RoE	Rules of Engagement
SAM	Surface to Air Missile
SEAD	Suppression of Enemy Air Defences
SLAM	Simple Land Analysis Model

### AUTHOR BIOGRAPHY

**Ian Campbell** is an analyst with Dstl. He is experienced in high-level combat modelling and has worked on a range of C3I-related studies. He has an honours degree in Aeromechanical Systems Engineering from Cranfield University.



# **C2 in COMAND**

**C<sup>3</sup> Orientated Model of Air and Naval Domains**

SAS - 039 Symposium

23 - 25 April 2002

Ian Campbell

# Outline

- Introduction
- C3ISR representation
- Joint modelling
- Validation
- COBP

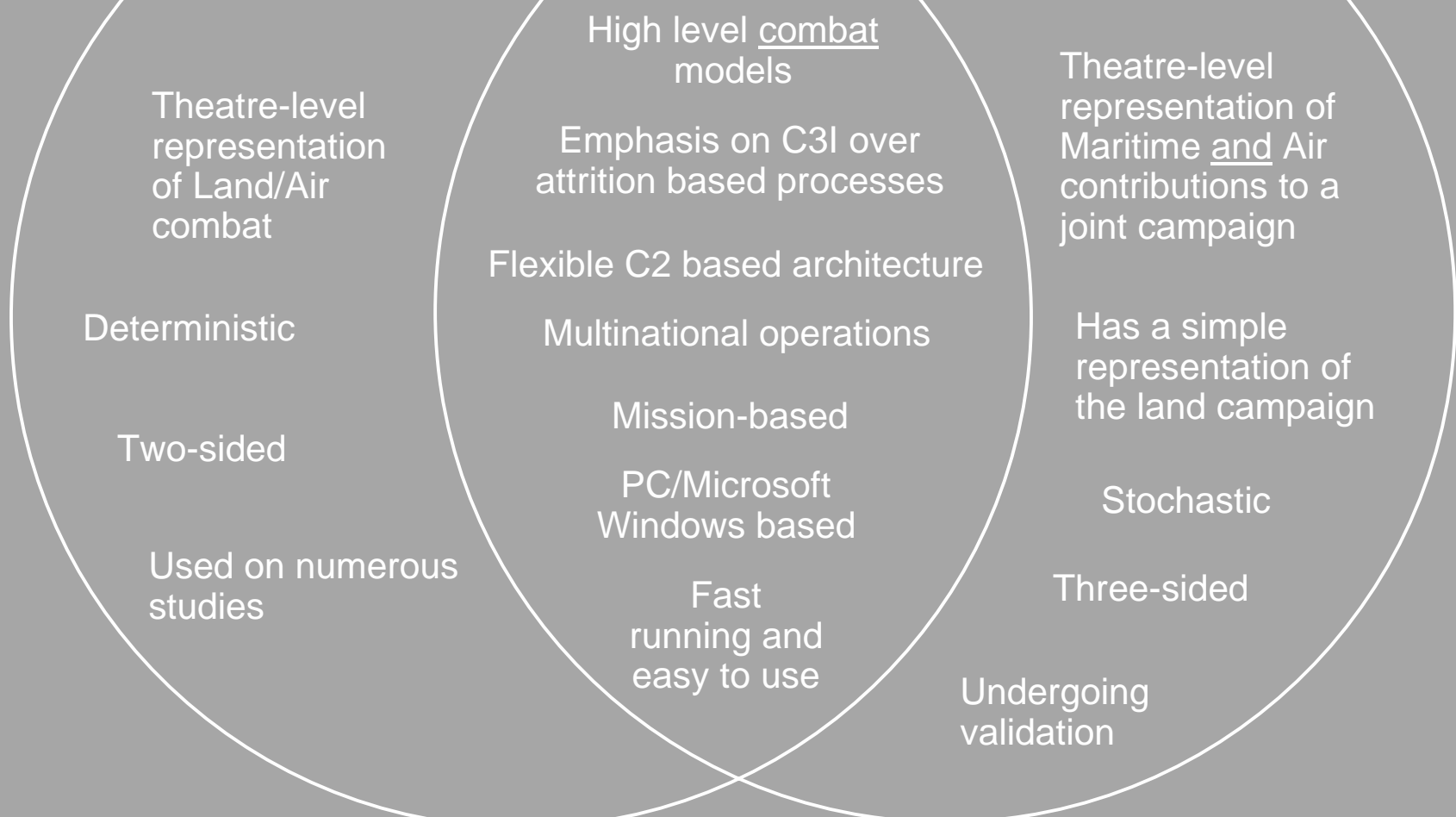


# CLARION

Combined Land/Air Representation  
of Integrated Operations

# COMAND

C3 Orientated Model of Air  
and Naval Domains



# C3ISR representation



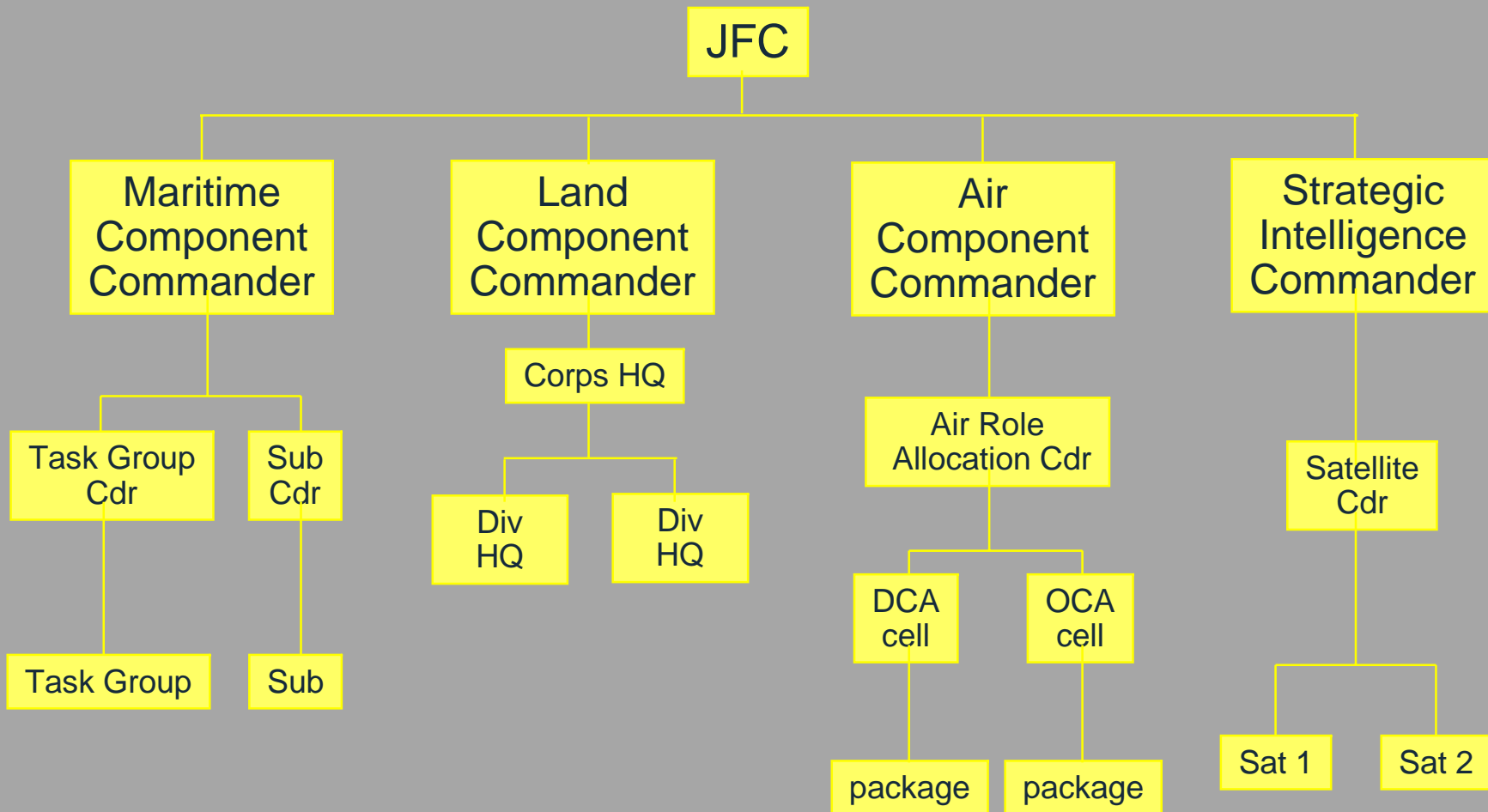
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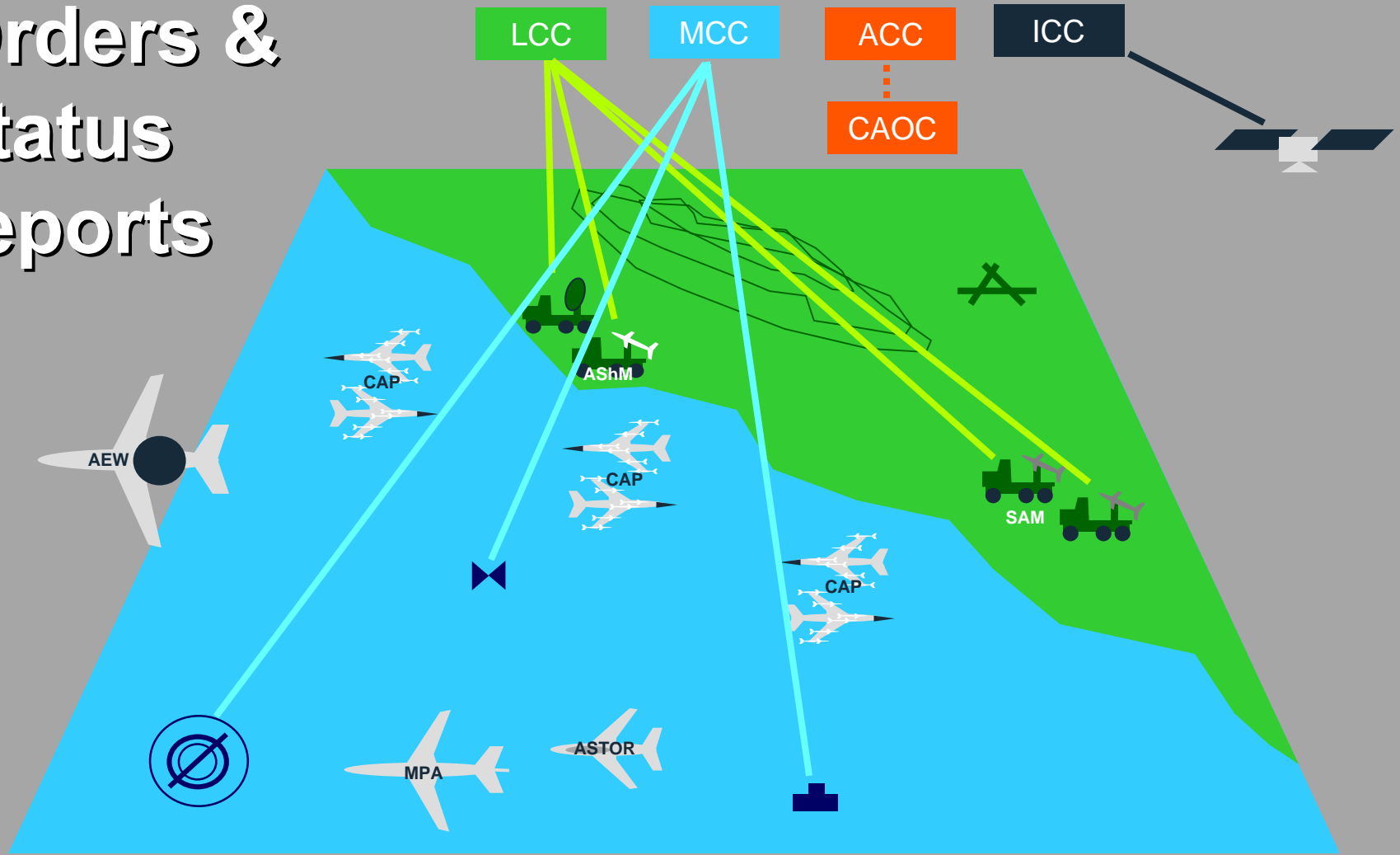


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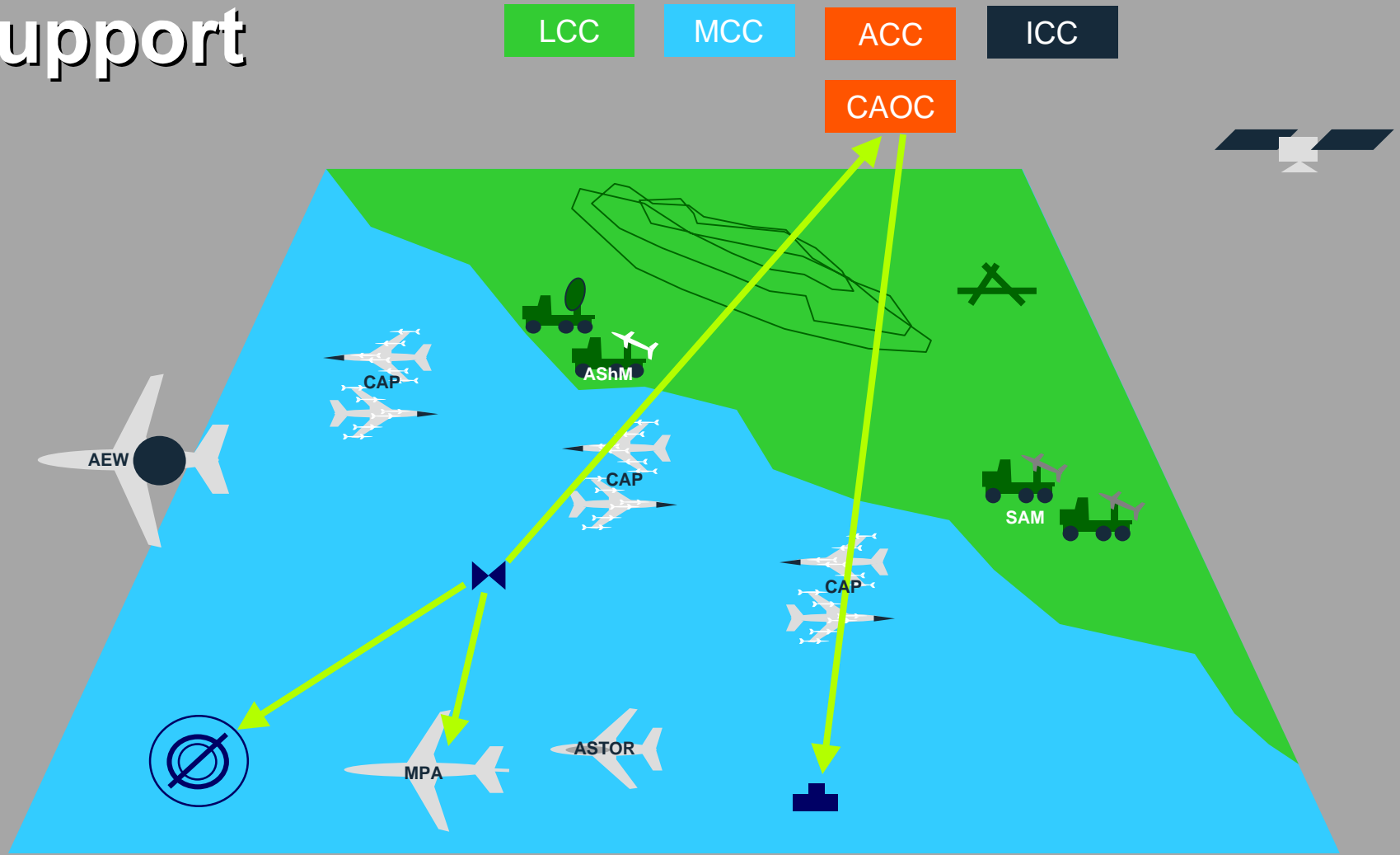
# Command hierarchy



# Comms - Orders & status reports



# Comms - Support



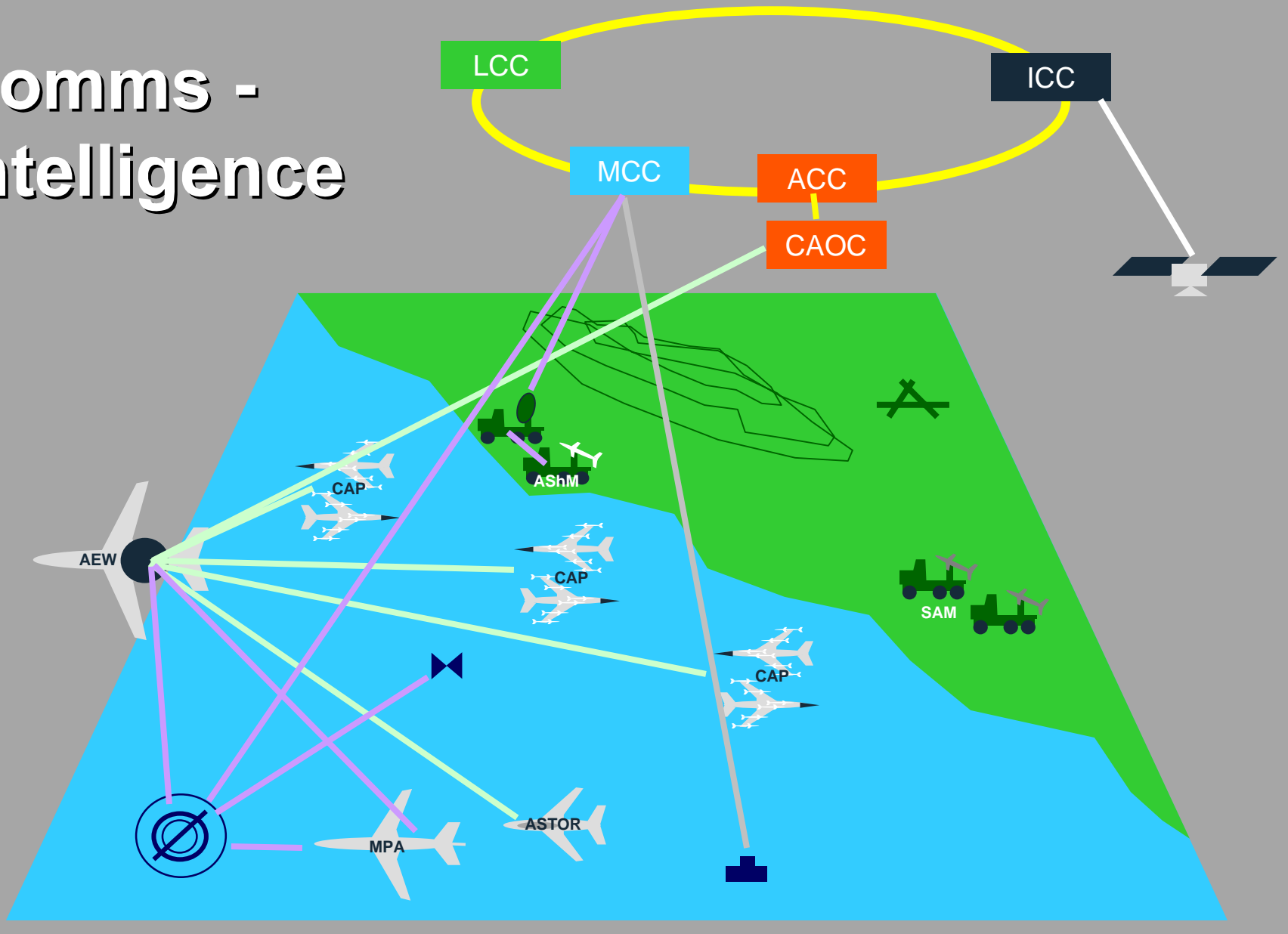
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# Comms - Intelligence



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# Missions and C2

- Maritime missions - Patrol an area, Move to an area, Escort an entity, Attack an entity, Track an entity.
- Air missions - Patrol an area (CAP, AEW, ASW/ASuW), Attack an entity (OAS, OCA, AI, ASuW) and Escort an entity.
- 'Deliberate' planning
- 'Rapid' planning

# Deliberate planning



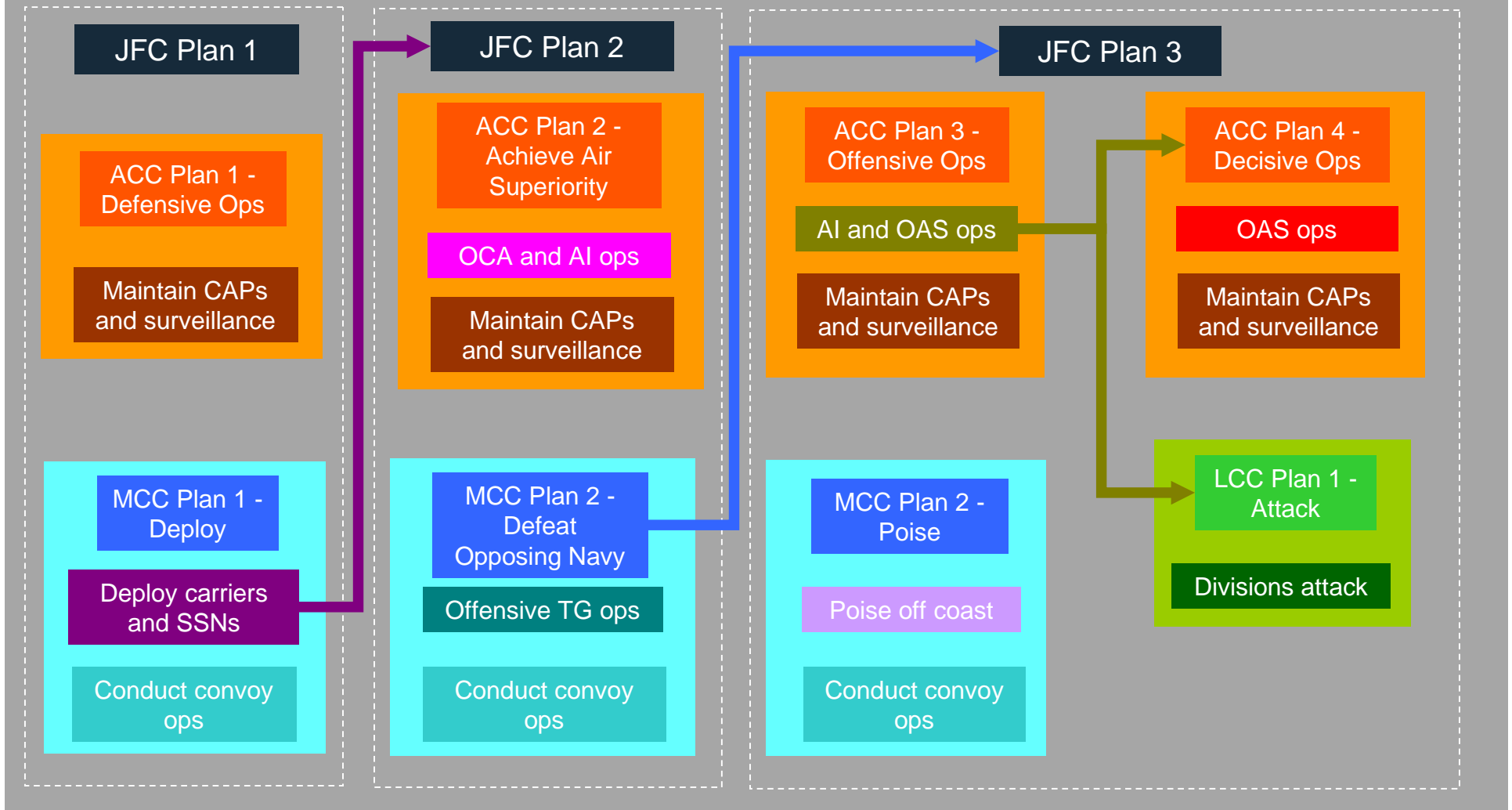
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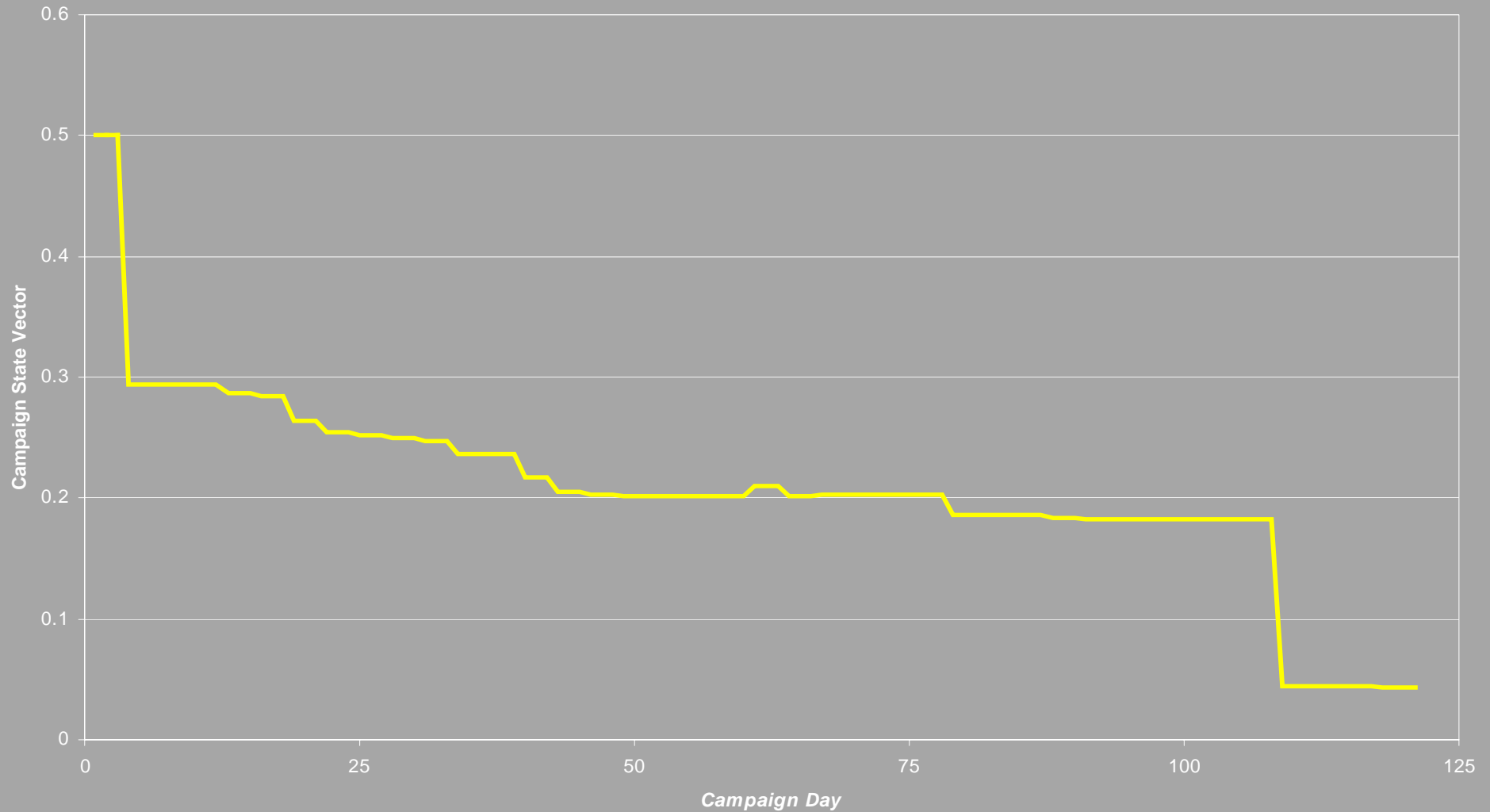
# Objectives



# Air C2

- Air C2 exercised by the ACC
  - Determines situation within each domain
  - Allocation to roles accordingly
  - Can decide not to fly each mission if risk deemed too high
  - Can request support from TLAM-firers

# Maritime CSV



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# Rapid planning



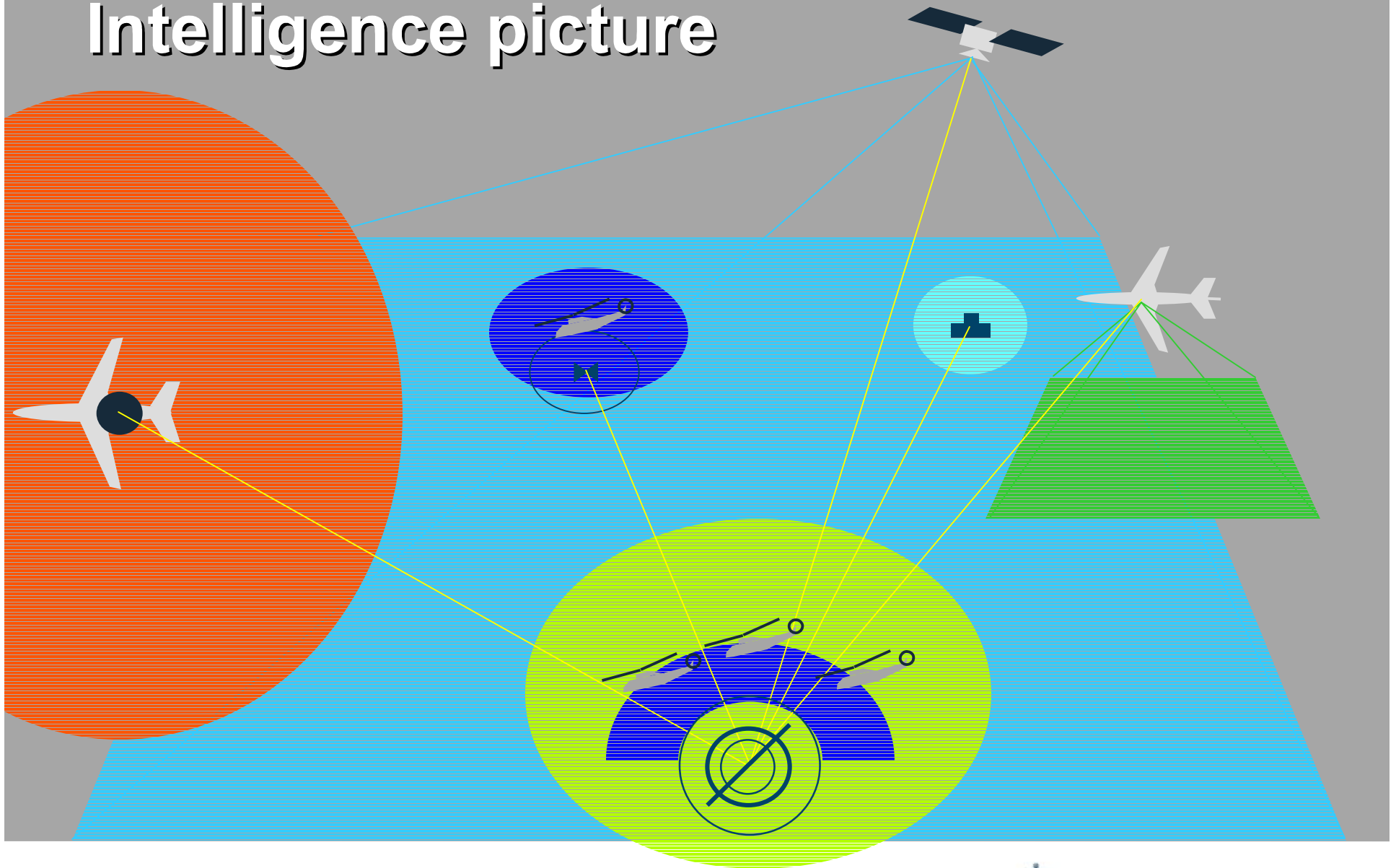
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# Intelligence picture



# Threat assessment

Defensive posture - threat range

Offensive posture - weapon range

Reaction based on capability of threat compared with own capability

Response may be to:

- evade
- attack
- request support
- any combination



# Joint modelling



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**B3-17**

# Manual joint modelling approach

Scenarios

ORBATs

Performance data

Concept of Operations

Successful OAS sorties

Availability of land forces

Availability of ISTAR assets

Availability of ship-based AH

Availability of NFS

**CLARION**

**COMAND**

**SLAM**

Duration of land campaign  
End strength of combatants  
Number of successful air  
attack sorties

# Historical validation - 1982 Falkland Islands Conflict



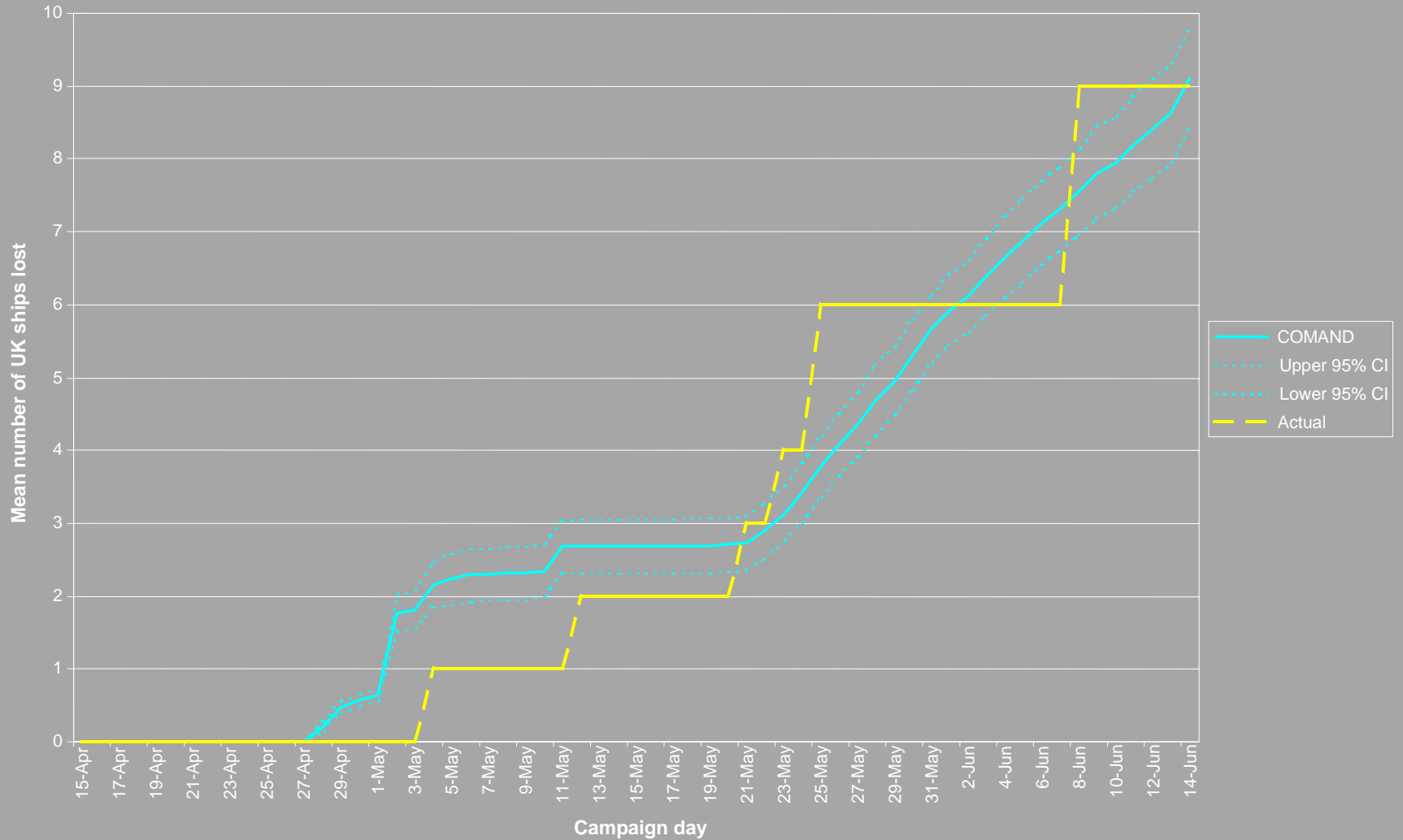
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# FI82 - UK ships lost over time



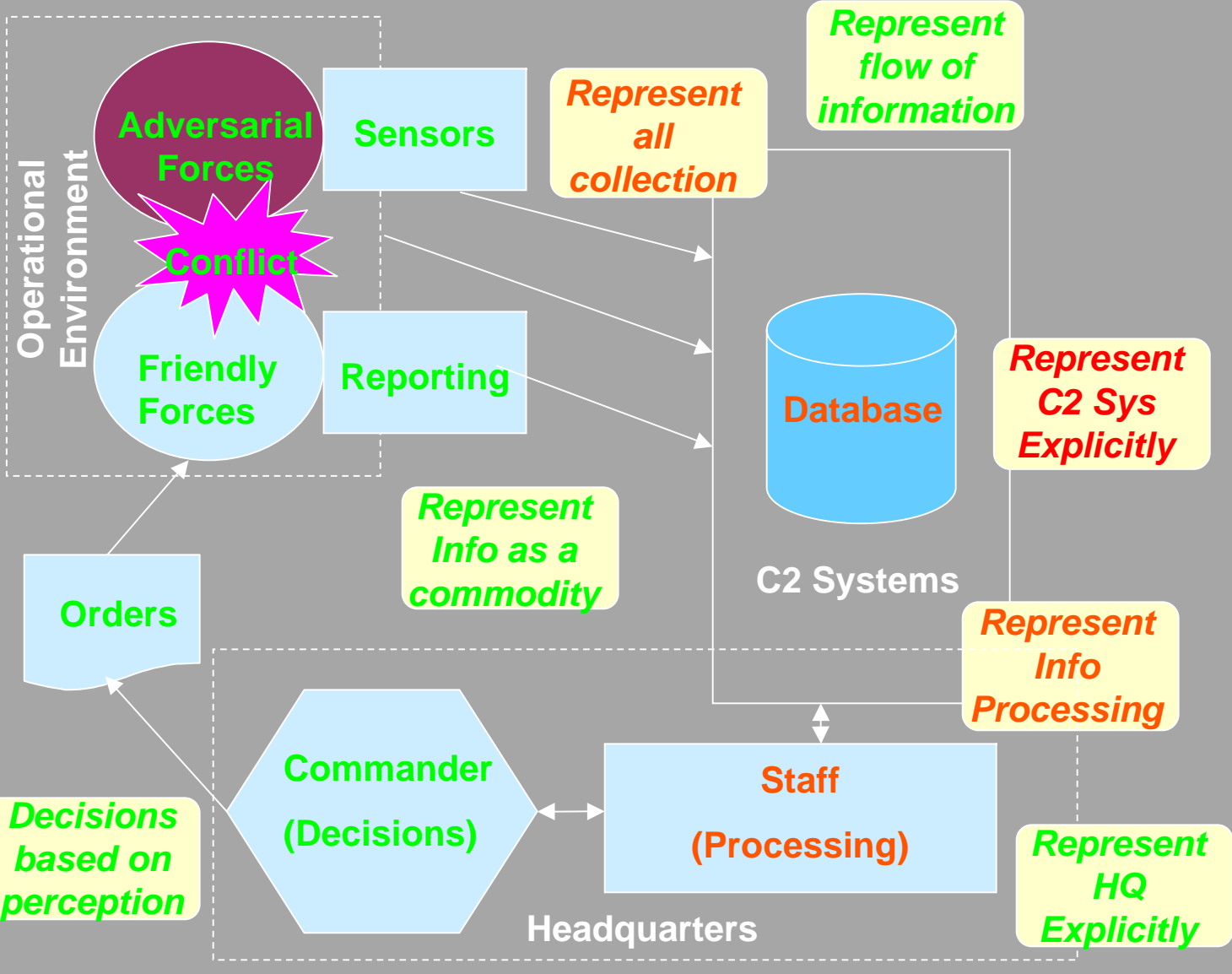
# Summary

- Although some initial teething troubles the C3ISR representation is working well
- COMAND is now being used on studies
  - primarily High Level ICS/ISTAR
  - assess the effect of ICS/ISTAR on campaign outcome
- Provides all stakeholders with a useful tool to assess the air and maritime contributions to the joint campaign

# COBP

*Represent IO by each side*

- Facilitates analysis of:*
- Human factors
  - PSYOPS
  - Deception
  - C2 System Effectiveness
  - Staff Structure



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# COBP

- 8-B-1 Representation of human behaviour
- 8-B-2 Homogenous vs federation
- 8-B-3 Stochastic vs deterministic
- 8-B-4 Adversary forces
- 8-B-5 VVA
- 8-D C2 modelling guidelines