C2 Architectures

What is Architecture?

At its most basic, clustering associated entities , intra-connecting within the clusters, and interconnecting between the clusters

Can refer to:—

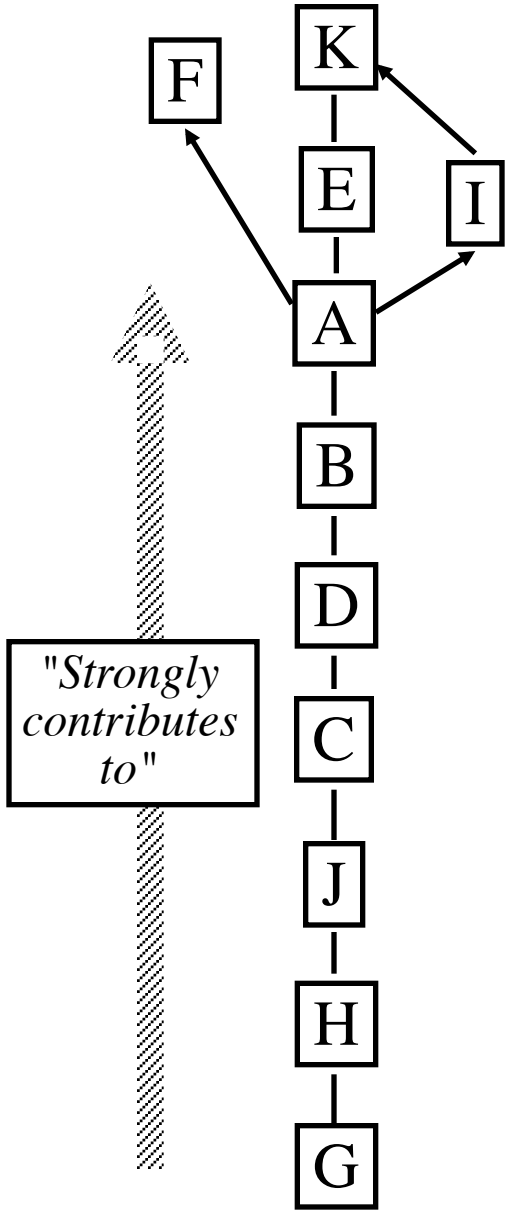
- People • Hardware • Software • Data • Information
- Platforms • Locations • Buildings • Towns & Cities
- Ideas • Perceptions

Related Terms:—

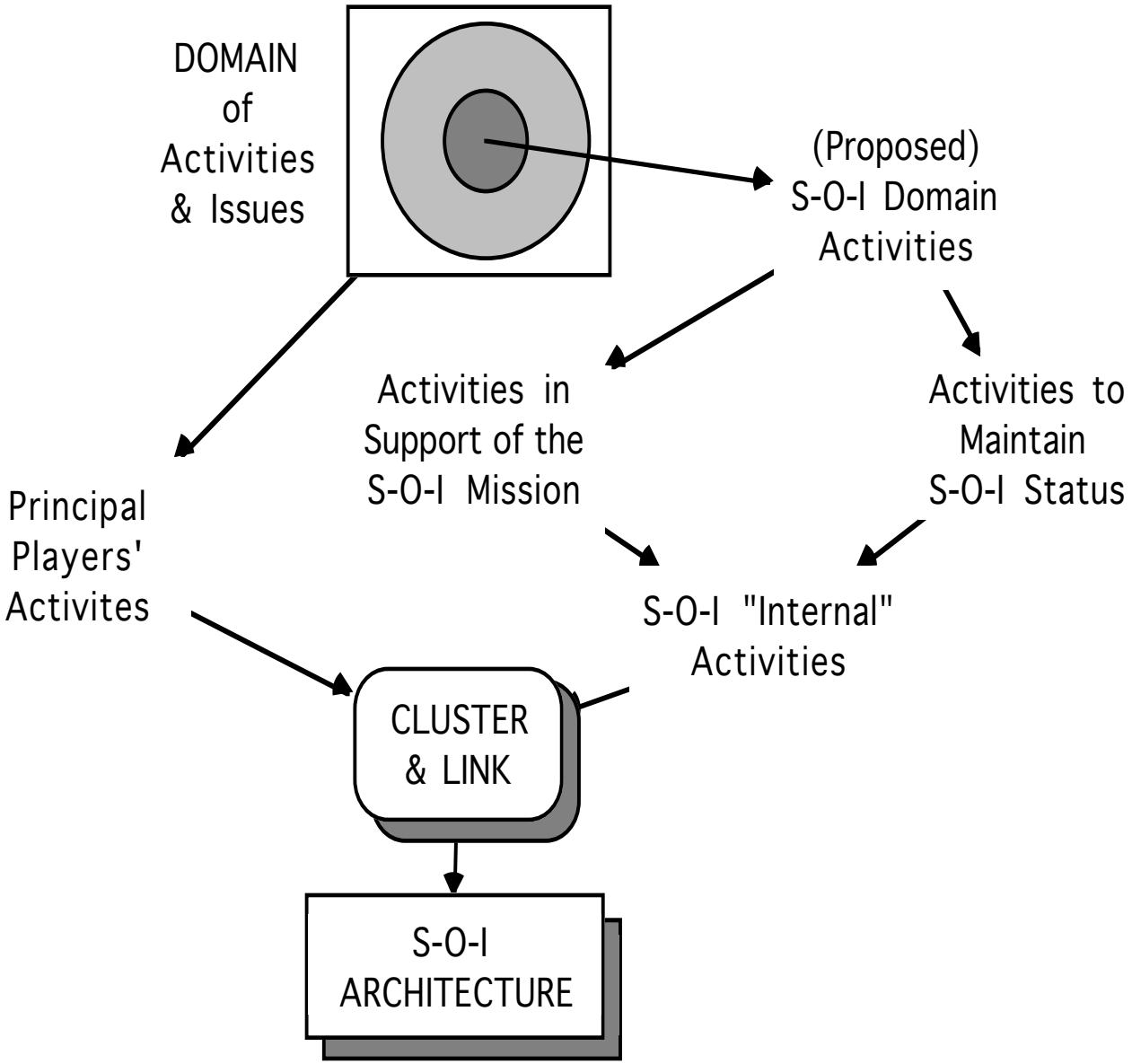
- Structure, the fabric/organization of a system
- Architectonics, the study of architecture, the organization of knowledge
- Topology, the study of shapes—particularly of invariances

Architecture Roles & Functions

A Group related entities so as to ease intra-communications, intra-relationships, reduce interface complexity
B Link groups, within the system and outside the system, so that coordination and control may effect synergy
C Provide a framework for overall system cohesion
D Reconfigure (redundant) assets to anticipate/ overcome internal threats—Availability—and external threats—Survivability
E Provide a resiliant framework for recovery from outage
F Provide a substrate for progressive implementation/ development
G Store transient information and knowledge of information location
H Acquire/share knowledge of entity and architecture fitness
I Support intermittently connected entities
J Adapt, evolve, self maintain
K Support a Mission

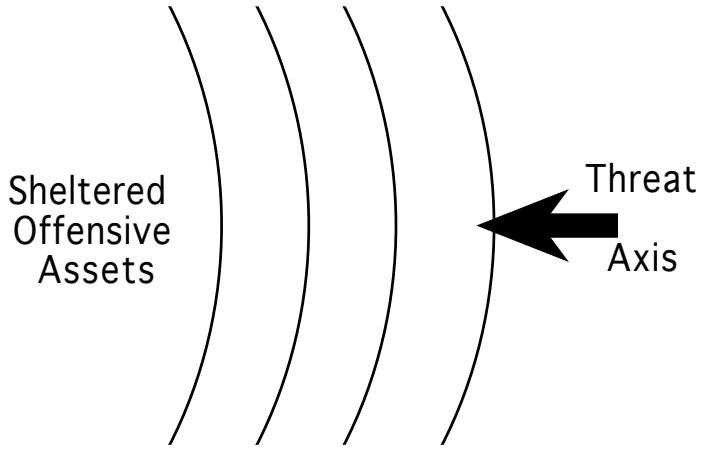


Developing Concepts of System Structure

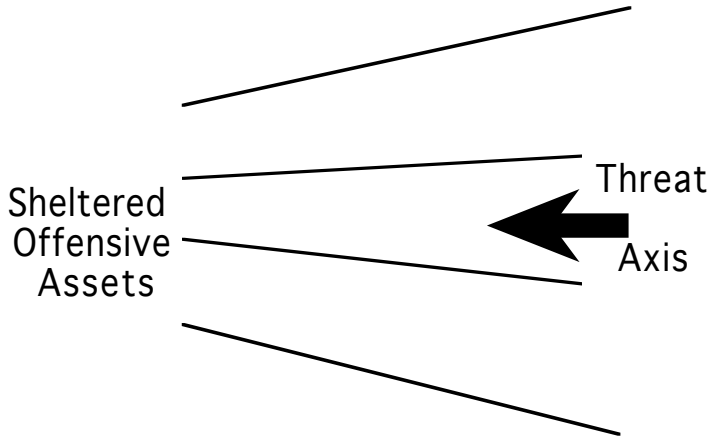


Defence Architectures will be considered, since these are less ephemeral than offensive architectures

Defence Force Architectures



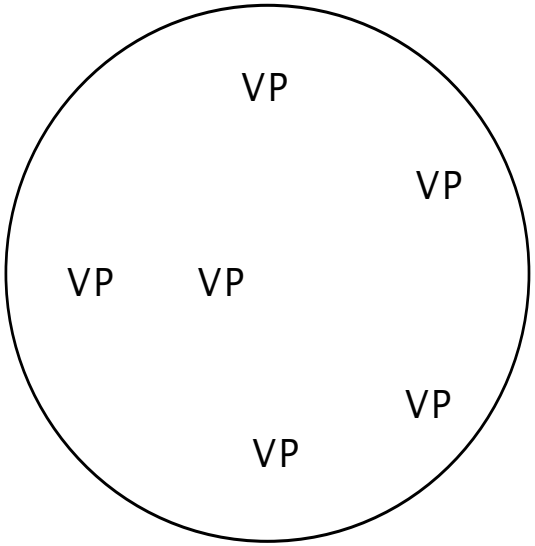
Layered Defence



Lane Defence

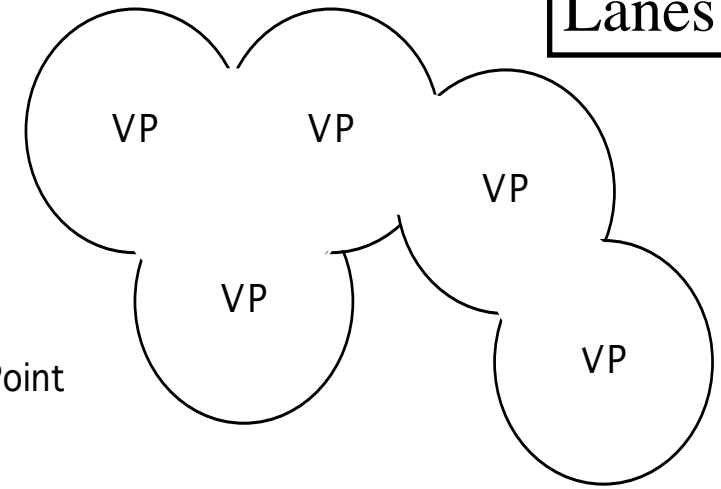
Archetypal Defence Schema

Types may be combined, e.g. Lanes in Layers



Area Defence

VP=Vital Point



Overlapping Point Defence

The Defensive C2 Task

In practical terms, the Defensive C2 Task is to coordinate the defensive assets so as to:—

- Deter • Counter aggression • Face a changing Threat Direction • Counter Diverse Threat Elements • Protect own Latent Offensive Forces • Distinguish Friend from Foe, esp. own Returning Offensive Forces
- Survive • Avoid Detection • Prevent Interception / Exploitation • Defend Defensive Assets • Defend own C2 • Tolerate Damage—redundancy, reconfiguration
- Be available • Reliable • Dependable • Maintainable • Transportable • Mobile
- Win the Cost-Exchange Ratio Battle—cost of Defence should not cost more than the Assets so saved, in the long term

Need Layer models from survivability Paper

The Great C2 Division

More Automation

"Threat is so awesome and swift that only fully-automated C2 systems have any chance of coping"

Human-Centred

"C2 Technology is not working. We don't know how to make software effective or reliable. Trained people are still the best bet."

Automation and the Perfect Defence

President Reagan's SDI—a Shield to Defend against ICBMs *so Effectively* that an Enemy could not gain Pre-emptive Strike advantage, would be deterred, and would find no benefit in ICBMs

Perceived Threat —Tens of Thousands of RVs + Decoys, some steerable on re-entry, NBC + Conventional W'heads, v. accurate, gen. high trajectories

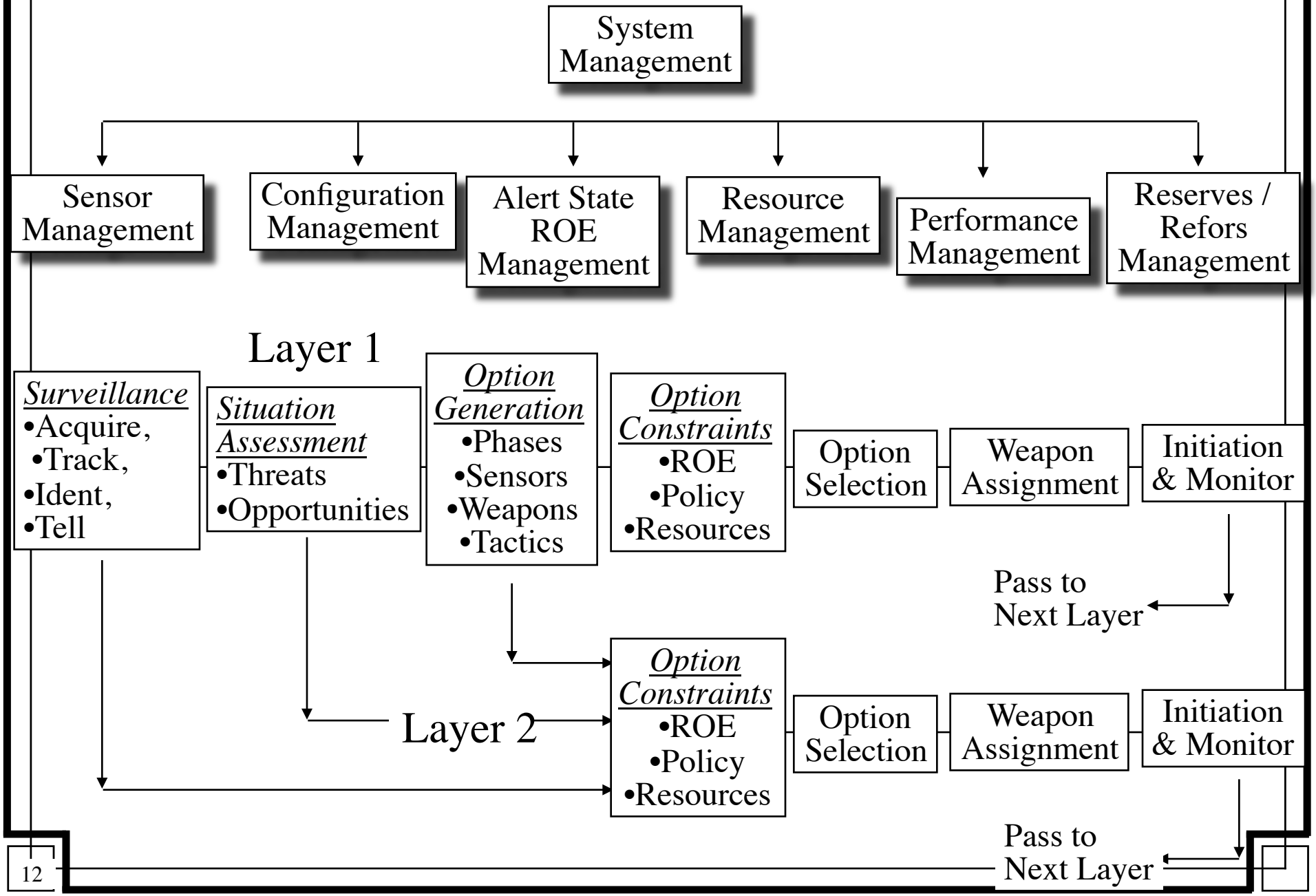
Threat Probability—Presently receding, accident still possible. Proliferation will increase risk over next decade

SDI Features

Fighting Mirror
Excalibur
Commsats, IONDS (Navstar)
Surveillance/Int Sats—Keyhole, Big Bear, IMEWS
Space-Based Radar
Space-Based, Networked Battle Stations
Ground-Based Radars (PAVE PAWS, COBRA DANE, etc)
NEACP

SDI Architecture must support the continuing operation of these assets despite attack and damage from physical, electronic, NBC, optical, Special forces, etc

SDI C2—Shield or Illusion?



Feasibility

Is it conceivable that a full-scale SDI multi-layered Defensive Shield could be fielded and be effective yet make no mistakes.

What about USS Stark? "They cannot really be attacking us"

What about the USS Vincennes? "Logically we must assume the target is hostile"

What about the Korean Airliner? "We warned those Koreans not to overfly our airspace"

What about our present limited ability to prove software *mathematically*? e.g. Safety Critical Software

What about our limited success with *sensor fusion*?

How do we predict the behaviour of a *partially-damaged* system as complex as SDI?

We face enormous difficulties doing *simple* things rigourously

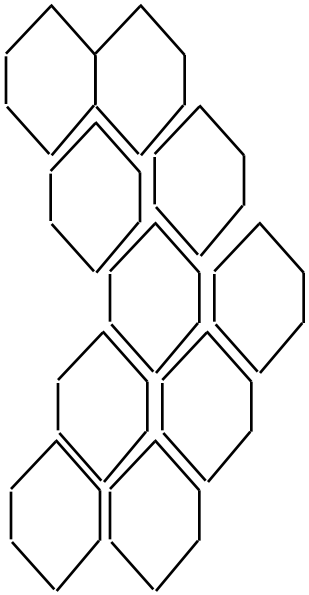
Small, National Forces

Likely Outcome of Social, Political, Economic and Technological Influences in Europe:—

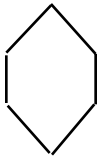
- Small Nationally-based Mobile Forces
- Minimal Command Structures
- Direct Political Control, Nation-by-Nation + Council of Nations
- Economic, Survivable, Quick Reaction, Out-of-Area Capable
- Potential for:—
  - —Disharmony
  - —Non-Interoperability

Could be Turned to Advantage

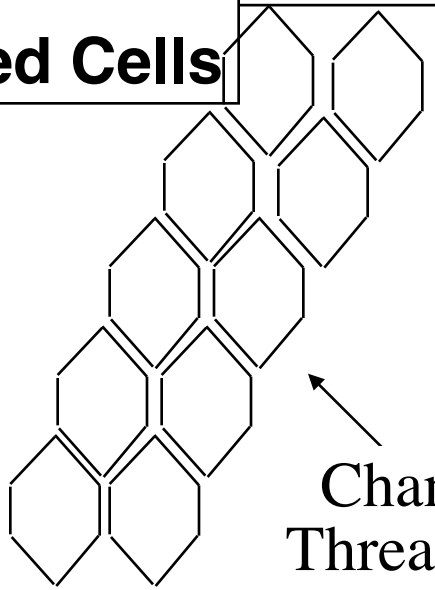
MOSAIC—Moveable, Semi-Autonomous Integrated Cells



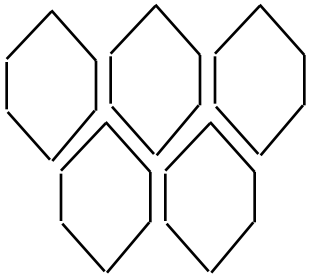
Threat Axis



Indigenous C2 Offence, Defence Air Support, Transport



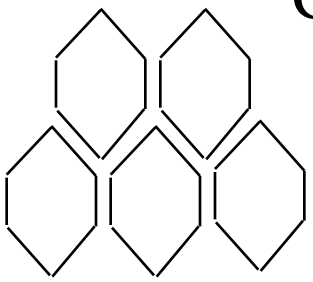
Changed Threat Axis

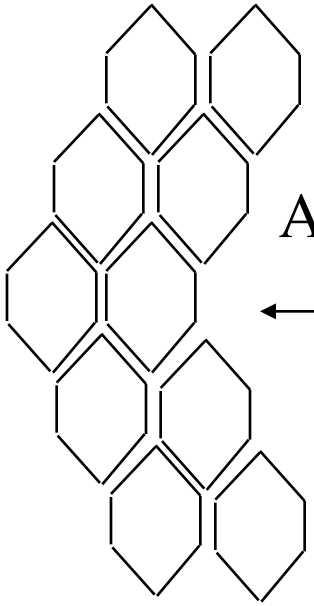


Lane A

Channel

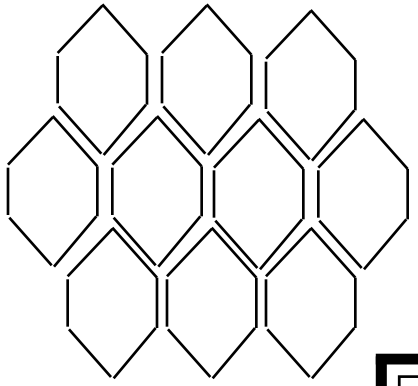
Lane B





Advancing Ground Threat

All-Round Threat



MOSAIC Implications

- National Expenditures, National Facilities, National Industries, National Interests
  - —each according to own perception of need
  - —each to agreed standards
- Protocols:—
  TADILs, INTDILs, ENGDILs, etc
- Manoeuvre Coordination:—
  Central C2 or Consensus
- Flexible, Mobile, Concentrated, Survivable

Multi-National Force Cohesion

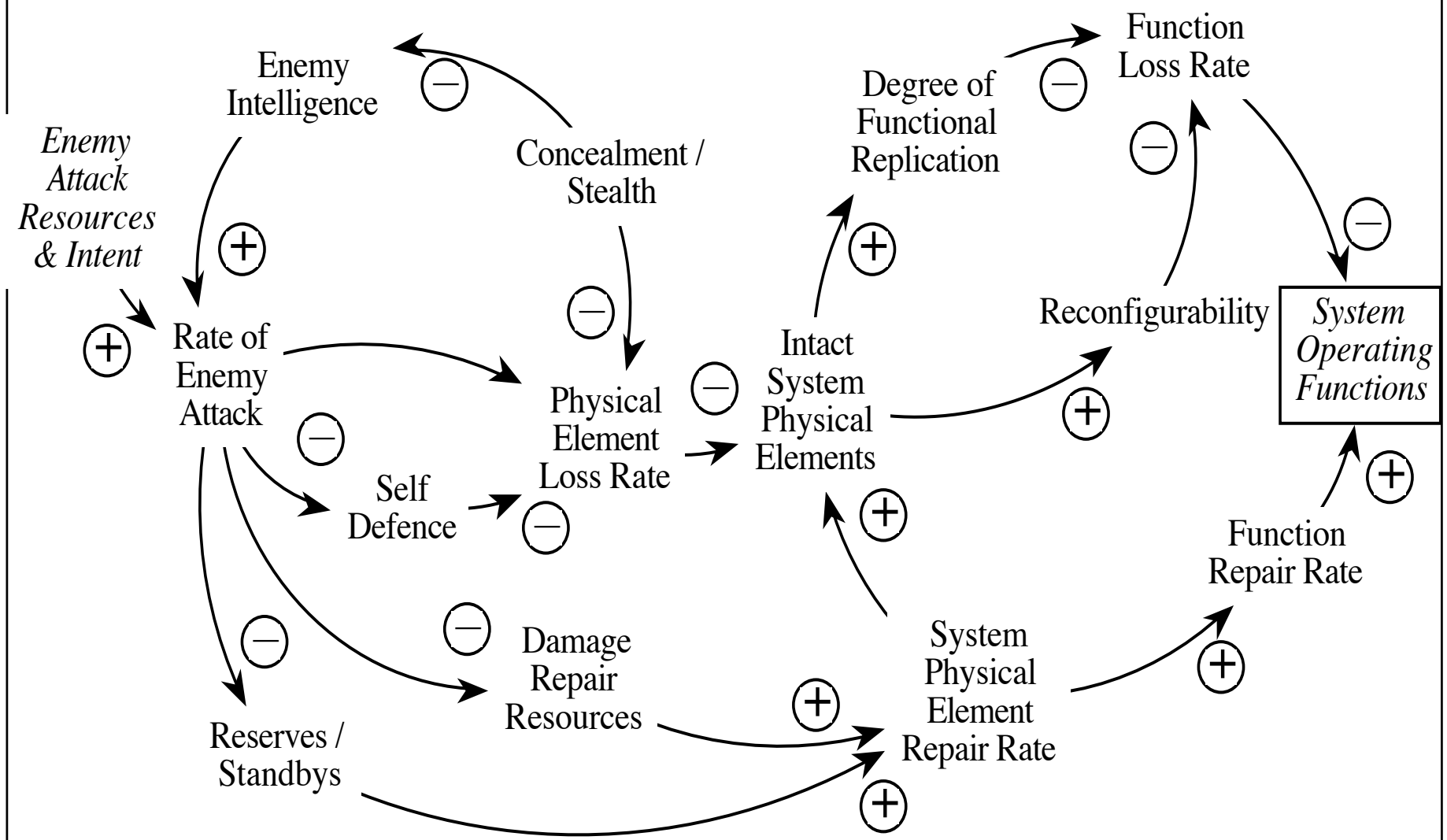
COHESIVE INFLUENCES	DISPERSIVE INFLUENCES
Common External Threat	—
—	Cultures / Attitudes
—	Languages
Common Training	Procedures
Interoperability	Common Protocols, procurements
—	Live, on-the-spot TV / Media
	= Public Revulsion, Anti-War
Lobby	
Commanders as PR men	= Amateur Tactical Reviews
Own Propaganda Machine	= Intelligence Threat
Public Awareness	Perceived Relevance (Out of
Area)	
Integrated C2, One Leader	Independent Political Force
Controls	

The C2 Law of Survivability

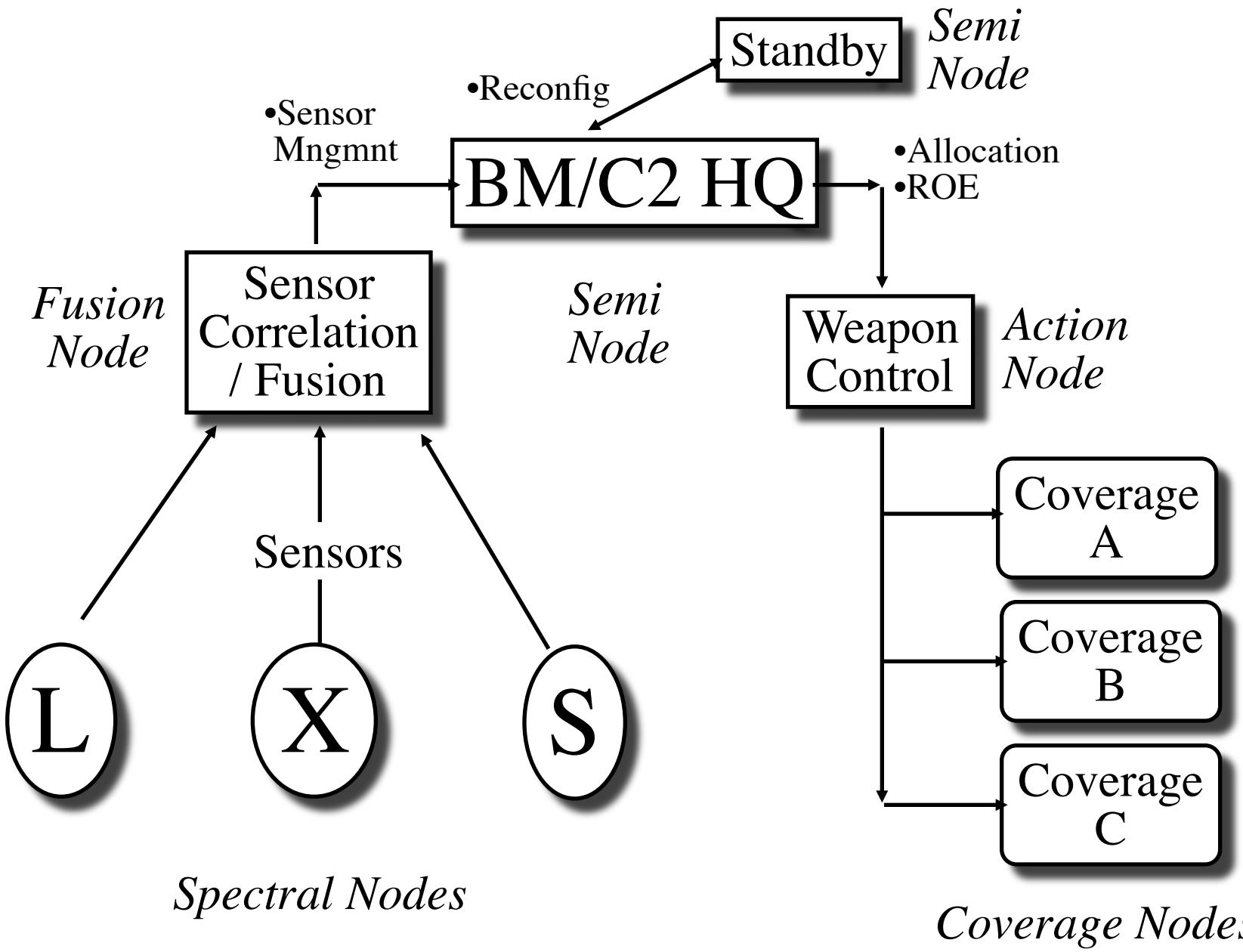
D K Hitchins

C2 Survivability is inverse both to the number of sequential, functional nodes in the C2 Process and to the degree of their exposure

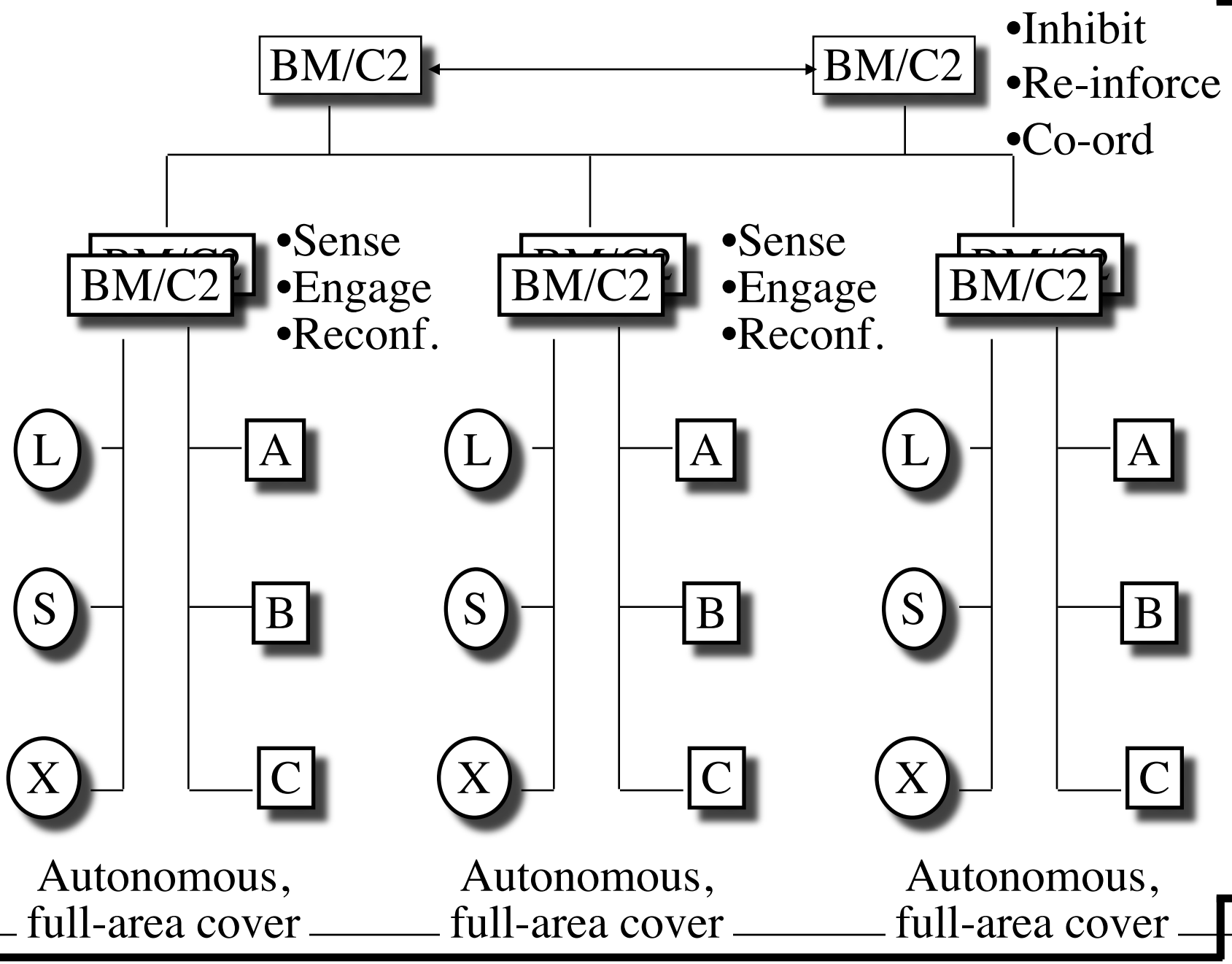
Basic Survivability Model



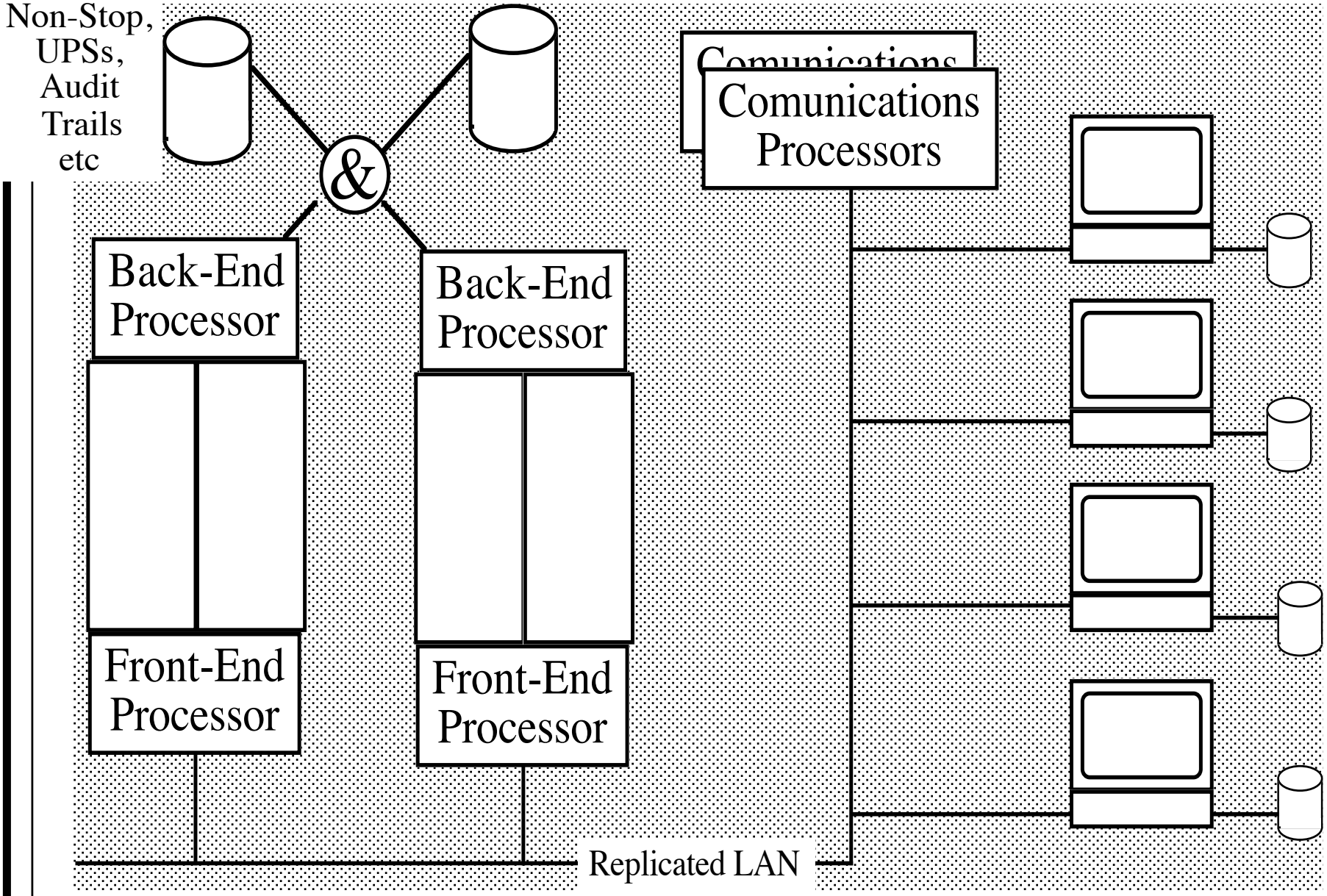
Functional Monopoly



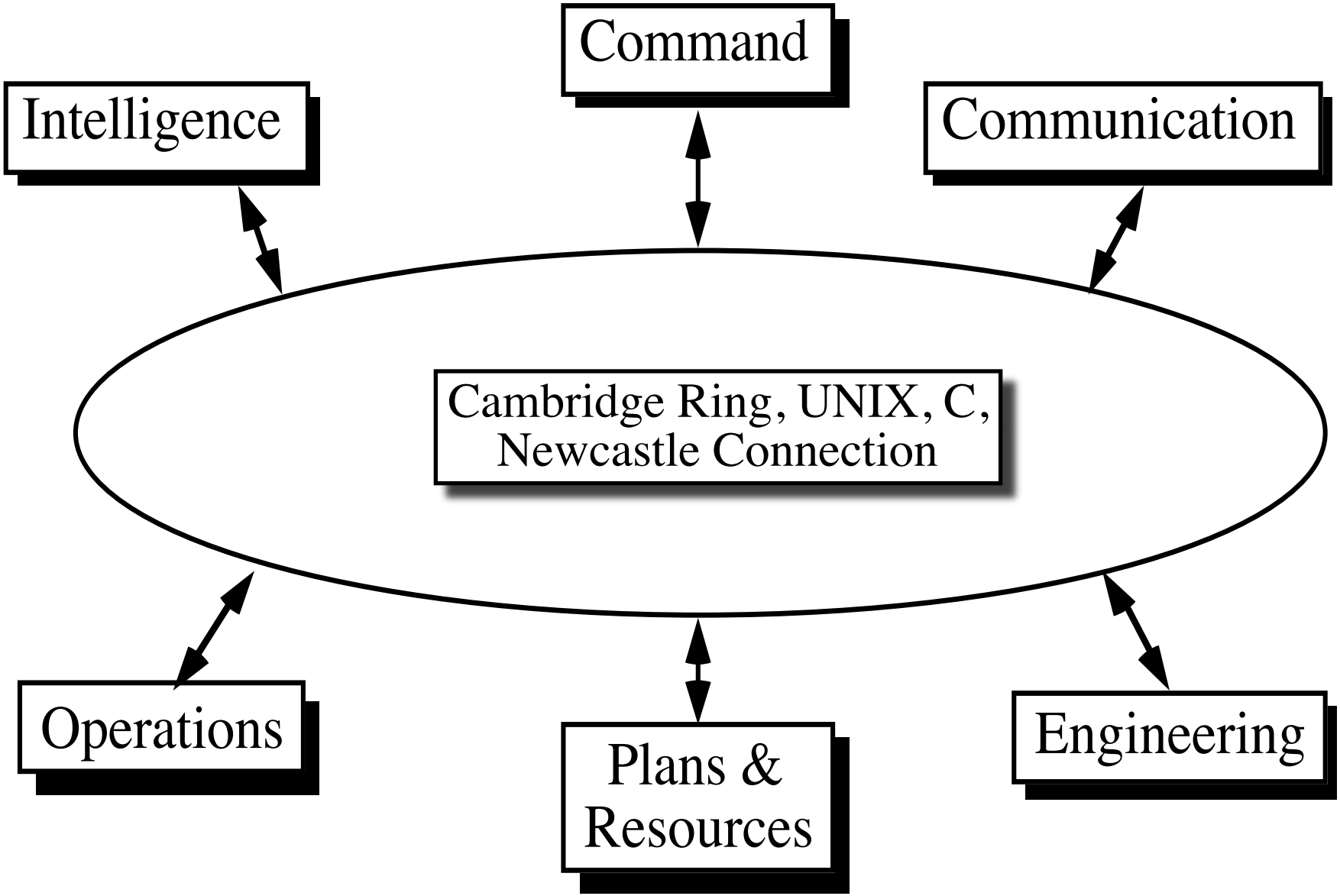
Functional Delegation



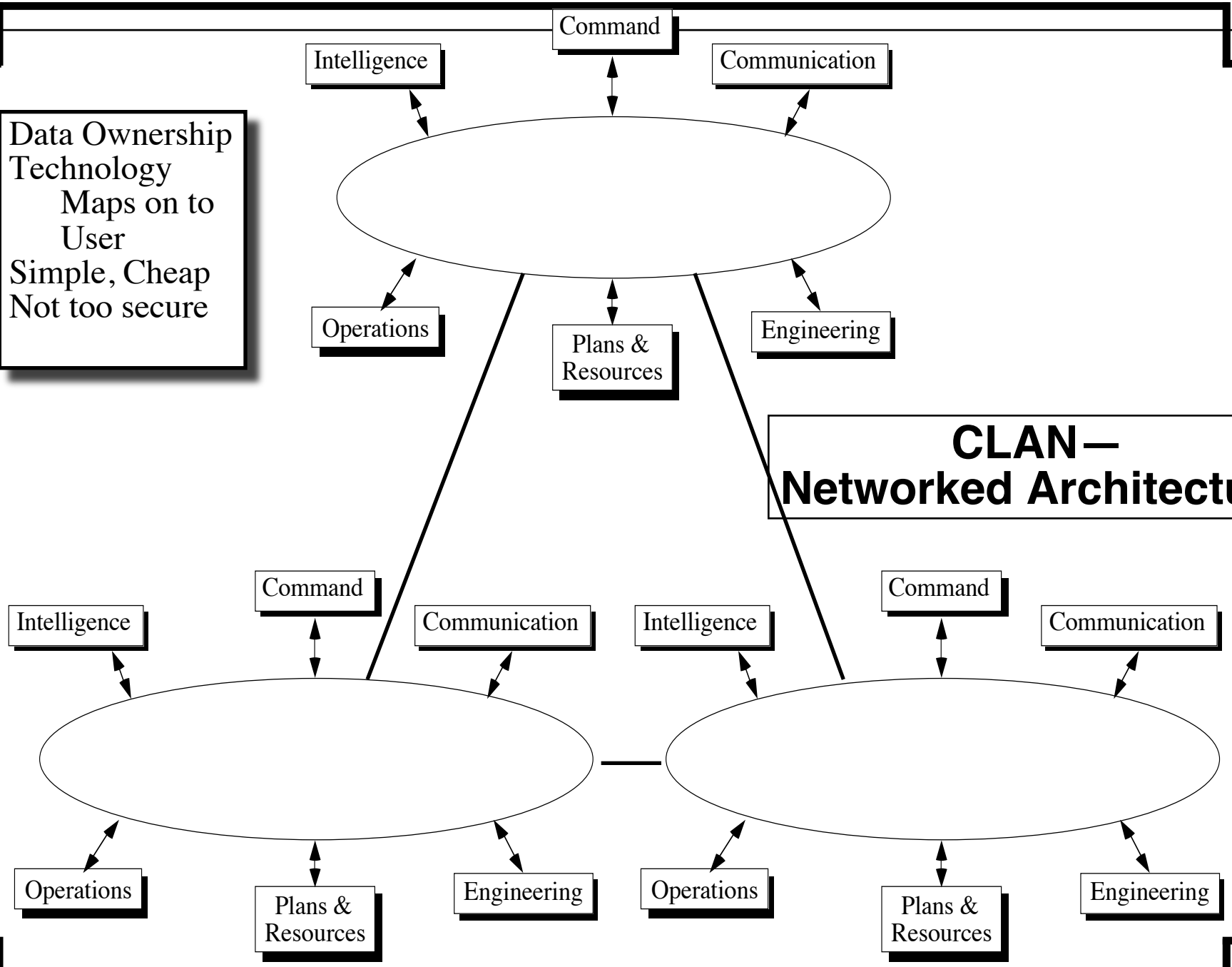
Typical Technological Architecture



CLAN—Functional Architecture



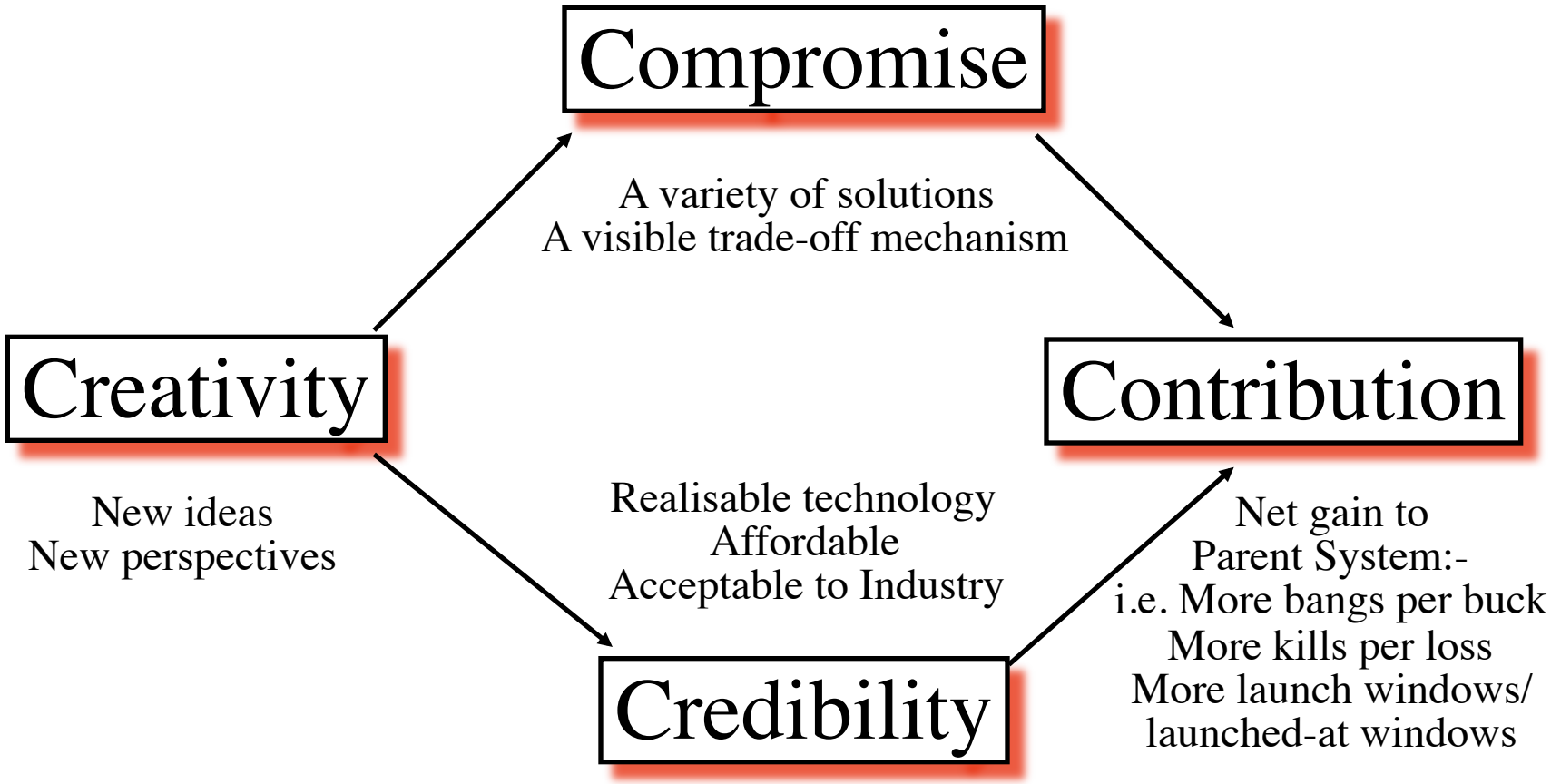
Data Ownership
Technology
Maps on to User
Simple, Cheap
Not too secure



CLAN—Networked Architecture

Advanced Avionics Architectural —A Case Study

A3 Innovation - the 4 Cs



Architectures Contribution

The Dreaded Force Multiplier!
Set up Parent System MOE
e.g. *More launch windows / launched-at window*
Divides into two parts

Ability

Getting there
Passive
Screening / Evasion / Stealth / EMCON

Approaching
Long-range sensors
Passive
Excess Power = agility + overtake

Engaging
Agility
Weapons / Fire Control / Crew flair

Recovering
Routes
Fuel / Damage tolerance

Vulnerability

Self Defence sensors
360 degrees
Passive
Not same as

Electronic Defences
Auto-contermeasures

Physical Defences
Auto-countermeasures

Agility / Crew flair
Excess Power / Training

Architecture Prime Directive

To provide an effective means for the concurrent management of mission, platform and resources

Semantic Analysis

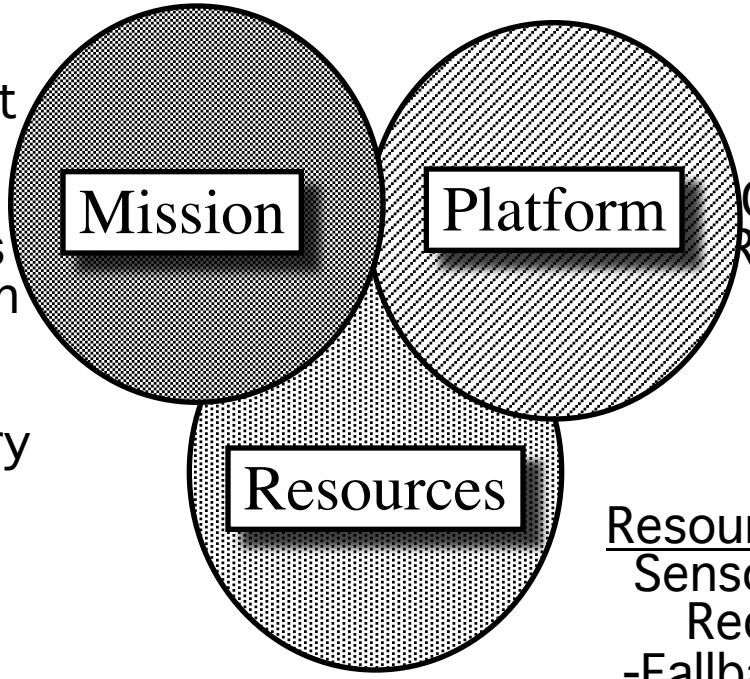
To provide.....A service to support...
...an effective.....performance, availability of performance and survivability of performance, giving.....
...means of.....a vehicle for conveying, processing and handling information in support of.....
...concurrent management.. simultaneous awareness, understanding and husbanding of capability for...
...mission.....the end-purpose of the particular set of activities to be effected by the aircraft.....
...platform.....the aircraft itself in respect of its ability to survive and support the mission and the .....
...resources.....sensors, emitters, weapons, power, energy, processing, communications, reserves, reversions allocated to the platform and its mission

IMPLIED

The contained architecture should show a net positive contribution to the effectiveness of its containing platform - i.e. any negative aspects, such as carried weight, loss of payload volume, etc should be more than compensated for by the S-O-I

Functional Management

Mission Management
Long-term Navigation
En - Route Evasion / Engagement
Situation Assessment
Threat Detection
Co-operation
Co-operative Tactics
Routes of Penetration & Egress
Evasion profiles
Engagement Geometry
ESM Interpretation
EMCON Policy
IFR Planning
Recovery



Platform Management
6-D Flight Regime Control
Fire Control
Engine Control
Tactical Manoeuvre
Energy Management
Glass cockpit Presentation
Reactive Counter-measures
Short-term Navigation

Resource Management
Sensor Management
Reconfiguration
-Fallback & Reversion
Fuel Management
Weapons Management
BITE / Self Test
Asymmetry Management

Clustering Drivers

NB These drivers operate at macro-functional level, i.e. they are not unnecessarily limited by physical boundaries

Spectral Overlap
Crew Visibility
Crew Armouring
Minimal Signal Loss
Resource Sharing
- PAs, Rxs, AEs
Temporal Competition
Accessibility
Functional Similarity

SEE HITCHINS / O'DWYER PAPER FOR LIST

Drivers in Detail

Some devices cluster because there is a need to allocate time and spectrum to their competing needs. Thus a focal, sophisticated processor is needed to trade between JTIDS, NIS, GPS, UHF / VHF, DME / VOR, etc

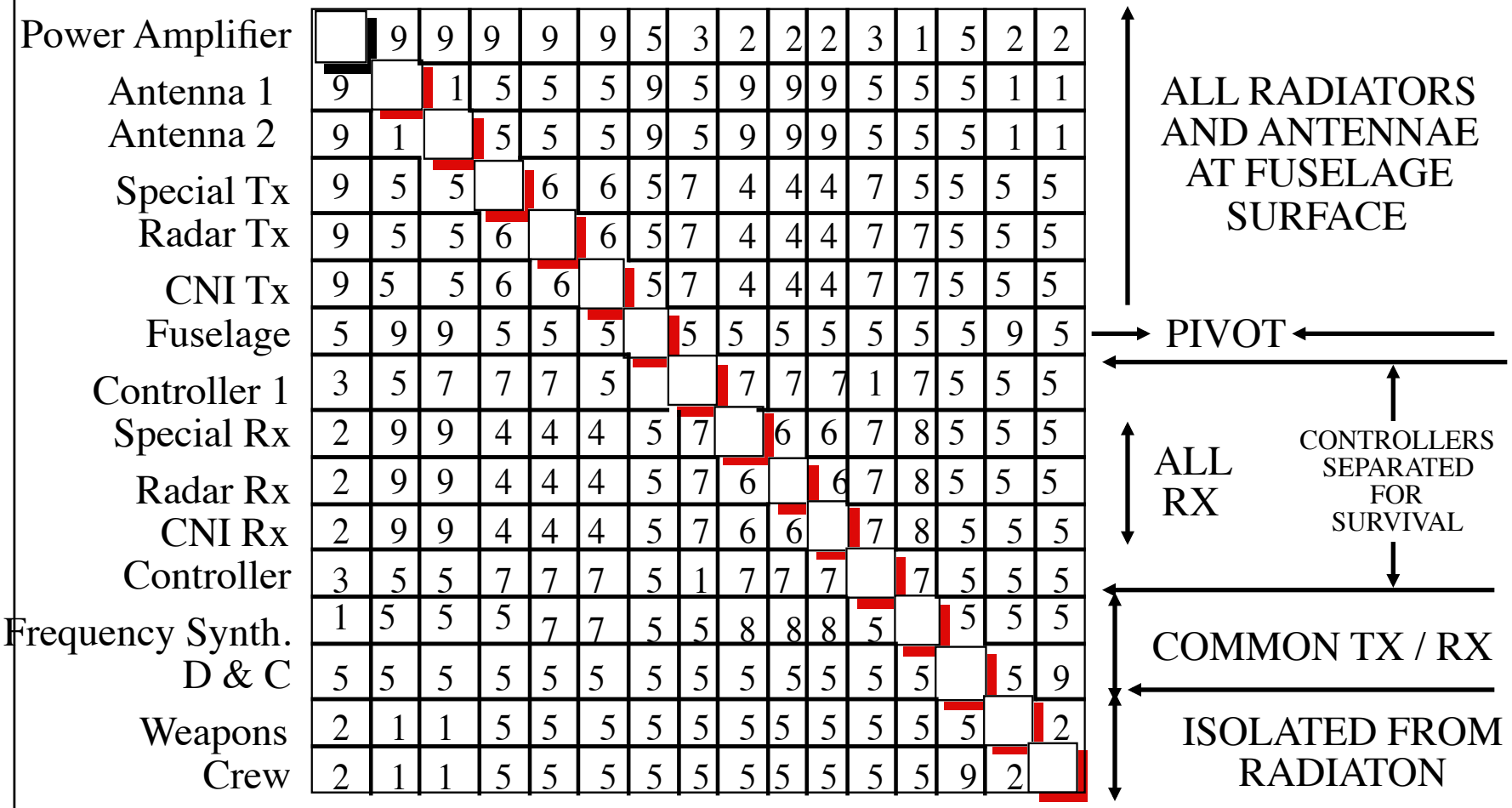
A similar spectral / temporal competition exists between radar and ESM, with modern, multi-mode radars seeking look-through for associated ESM. Such radars are moving towards fully electronically-scanned antennae working for both devices.

Since ESM tends to cover 0.2 - 18GHz, there is potential for a restructuring - e.g. one processor to arbitrate over 0.2 - 2GHz and a second to cover 2 - 20 GHz

Would such a restructuring help? Hard to tell, there are so many other factors to take into account at the same time.

Anti-Clustering Drivers

Centre of Gravity
Available package volumes
Fuselage surface window competition
Tx / Rx isolation
Electro Magnetic Compatibility
Number of connections
- reliability / maintainability
Damage tolerant redundancy
Heat Dissipation
Local environment



Advanced Architecture - Second Moment

Results of A3P Investigation

- Separate High Power and Low Power Systems
- Rationalize both groups to share common resources, saving weight, increasing availability
- Use Avionics as shield for crew—shape avionics to conform to the fuselage shape—Conformal Avionics
- Isolate Crew and Weapons from EM Radiation
- Disperse redundant components for enhanced survivability
- Locate sensitive receivers at their antennae—ie at the fuselage skin, to reduce noise, transmission losses

Simple, high-level Architecture analysis, but revealing important, traceable, justifiable new concepts