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 resilient 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

"Strongly contributes to"
Developing Concepts of System Structure

DOMAIN of Activities & Issues

(Proposed) S-O-I Domain Activities

Activities in Support of the S-O-I Mission

Activities to Maintain S-O-I Status

S-O-I "Internal" Activities

Principal Players' Activities

CLUSTER & LINK

S-O-I ARCHITECTURE
Defence Architectures will be considered, since these are less ephemeral than offensive architectures.
Defence Force Architectures

Layered Defence

Sheltered Offensive Assets

Threat Axis

Sheltered Offensive Assets

Lane Defence

Archetypal Defence Schema

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

Area Defence

VP=Vital Point

Overlapping Point Defence
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
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."
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?

System Management

Sensor Management
Configuration Management
Alert State Management
ROE Management
Resource Management
Performance Management
Reserves / Refors Management

Layer 1

Surveillance
• Acquire,
• Track,
• Ident,
• Tell

Situation Assessment
• Threats
• Opportunities

Option Generation
• Phases
• Sensors
• Weapons
• Tactics

Option Constraints
• ROE
• Policy
• Resources

Option Selection
Weapon Assignment
Initiation & Monitor

Layer 2

Option Constraints
• ROE
• Policy
• Resources

Option Selection
Weapon Assignment
Initiation & Monitor

Pass to Next Layer

Pass to Next Layer
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 \textit{mathematically}? e.g. Safety Critical Software What about our limited success with \textit{sensor fusion}? How do we predict the behaviour of a \textit{partially-damaged} system as complex as SDI? 

\textbf{We face enormous difficulties doing \textit{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

Lane A
Channel
Lane B

Advancing Ground Threat

Changed Threat Axis

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

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<td>Integrated C2, One Leader Controls</td>
<td>Independent Political Force</td>
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C2 Survivability is inverse both to the number of sequential, functional nodes in the C2 Process and to the degree of their exposure
Functional Monopoly

BM/C2 HQ

- Sensor Correlation / Fusion
  - Sensor Mngmnt
  - Reconfig

Semi Node
- Allocation
- ROE

Standby

Semi Node

Weapon Control

Action Node

Coverage Nodes
- Coverage A
- Coverage B
- Coverage C

Spectral Nodes

Coverage Nodes

Fusion Node

Sensors
- L
- X
- S
Functional Delegation

- BM/C2
  - Sense
  - Engage
  - Reconf.

- BM/C2
  - Sense
  - Engage
  - Reconf.

- BM/C2
  - Inhibit
  - Re-inforce
  - Co-ord

- L
- A
- B
- C

Autonomous, full-area cover

- L
- A
- B
- C

Autonomous, full-area cover

- L
- A
- B
- C

Autonomous, full-area cover
Typical Technological Architecture

- Front-End Processor
- Back-End Processor
- Replicated LAN

- Non-Stop, UPSs, Audit Trails etc

- Communications Processors

- Replicated LAN
CLAN—Functional Architecture

- Intelligence
- Command
- Communication
- Operations
- Plans & Resources
- Engineering

Cambridge Ring, UNIX, C, Newcastle Connection
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

Compromise
A variety of solutions
A visible trade-off mechanism

Creativity
New ideas
New perspectives

Contribution
Net gain to Parent System:
- i.e. More bangs per buck
- More kills per loss
- More launch windows/
  launched-at windows

Credibility
Realisable technology
Affordable
Acceptable to Industry
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
- Recovering
  - Routes
  - Fuel / Damage tolerance

**Vulnerability**
- Self Defence sensors
  - 360 degrees
  - Passive
- Not same as
- Electronic Defences
  - Auto-countermeasures
- Physical Defences
  - Auto-countermeasures
- Agility / Crew flair
  - Excess Power / Training
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
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