Mapping Acquisition Requirements from Capabilities in a Net-Centric Enterprise – Creating a Capabilities Engineering Framework

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Software System Acquisition Problem Areas

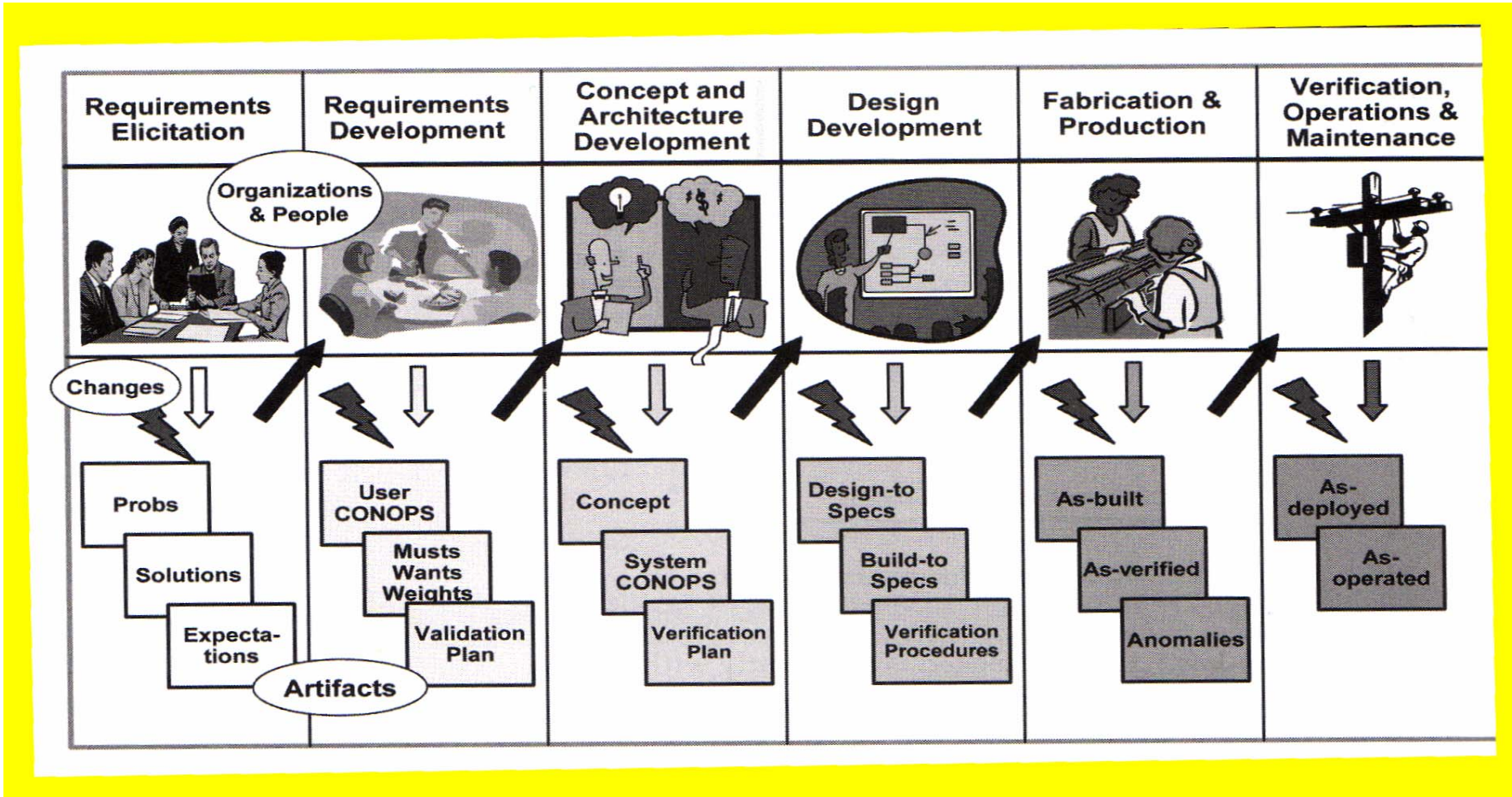
Requirements Always High on the List

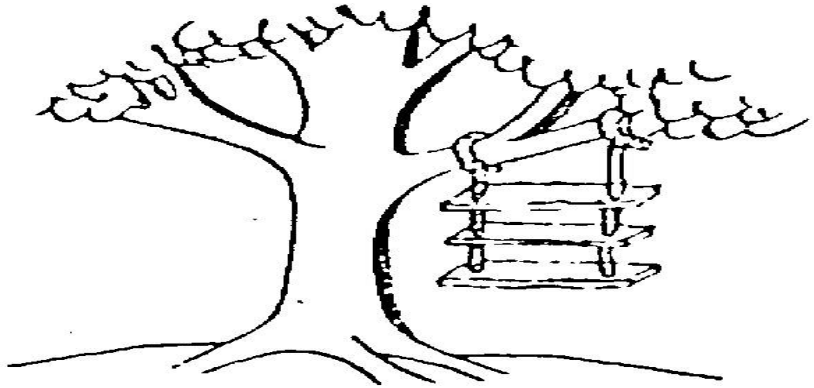
- **ACAT I Acquisition Programs under scrutiny (GAO 04-393) – significant issues published**
- **Boehm : 'Reasons Why Programs Fail' – Inadequate Requirements a major causal factor**
- **Sandish Report and others: Inadequate requirements source of cost and schedule overruns and performance shortfalls**

Little Evidence of Requirements Engineering in place

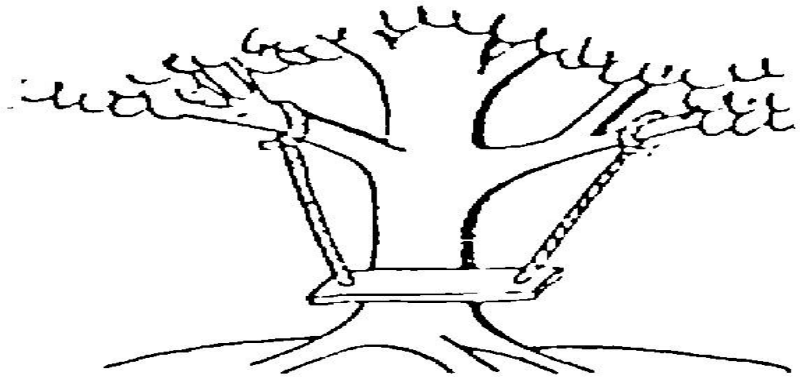
	Project Management Best Practices	Skills Training	Software Architecture	Requirements	Interoperability	Process
DSB 2000 Report	✸	✸	✸	✸		✸
Army Lessons Learned Workshop	✸	✸	✸	✸		✸
FBCB2 Arch. Study			✸	✸		
TAI - Systemic Analysis	✸	✸	✸	✸		✸
SECs' Top-5 Problems	✸	✸	✸	✸	✸	✸
PMO Survey	✸	✸		✸	✸	✸
Emerging Benchmark Results	✸	✸	✸	✸	✸	✸

Classic Requirements Management

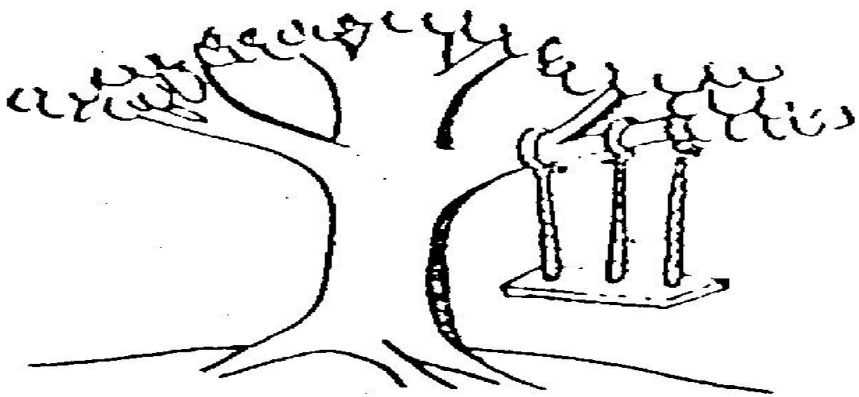




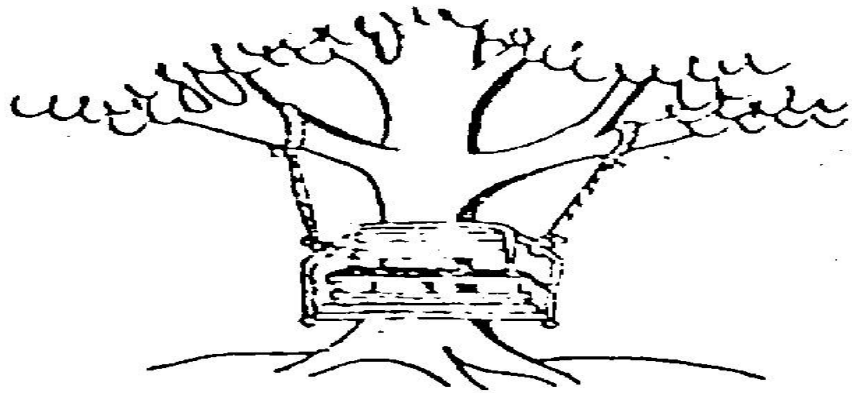
As Operations Requested It



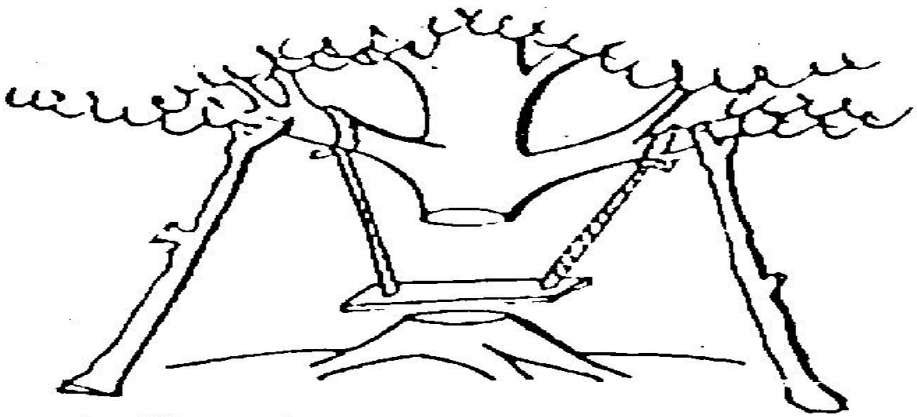
As Engineering Designed It



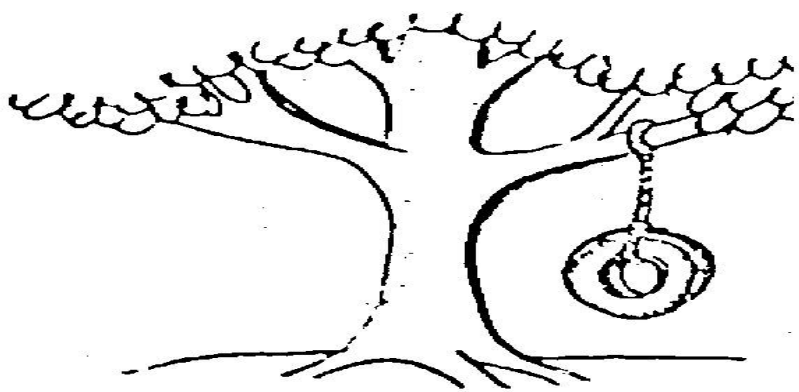
As Procurement Ordered It



As Accounting Paid For It



As Plant Maintenance Installed It



What the Soldier Wanted!

The Capability Turn in Requirements Development: A Domain-Centered Approach

Software quality in digitized systems depends on how well the software represents and is responsive to the domain contexts in which the systems operate.

A capability driven approach* builds on domain centered approaches – capabilities are defined wrt to a context containing multiple domains.

User-driven, domain-driven & capability-driven approaches to software intensive system acquisition all point in a similar direction –

The voice of the customer, in this case the warfighter, must be heard down to the software technologist.

The voice of the software technologist has to be heard by the warfighter

* Capability driven approaches in the military stem from the Joint Capabilities Integration and Development System (JCIDS) created by the Chairman of the Joint Chiefs of Staff (CJCS)

The Capability Turn in Requirements Development: Difficulties

In the US military, capability driven approaches are difficult to implement due to

- the huge numbers of people involved and their very different perspectives (e.g., warfighter vs. bureaucrat vs. technologist)
- the rapidly changing and uniqueness of threats
- the pace of information technology.

From analysis of 10s of 1000s of Problem and Trouble Reports it appears that capability driven approaches are not informing the software as well as they could.

- Software problems are not stated in terms of capabilities being adversely affected
- Software solutions do not refer to how enablement of capabilities can be improved

Overcoming Difficulties for the Capability Turn:
A Framework for Capability Engineering

The aim of Capability Engineering (CE) is to meet the challenges capability & domain driven approaches face.

CE is the mutual formulation of joint capabilities and acquisition requirements for multiple

- platforms
- systems/subsystems that work with or in these platforms.

CE supports traceability and validation of requirements specifications from capabilities

The Capability Engineering Framework (CEF) provides knowledge management support for CE.

The CEF identifies, annotates and organizes exemplary practices.

The Five Dimensions of CEF

The five CEF ***Dimensions*** organize and document support for "good practices" in capability engineering:

1. **Organization** – the infrastructure of virtual organizations, which are multiple organizations using both on-line and face-to-face interaction in an integrated fashion.
2. **Process** – the production of work products and ultimately the product itself, especially to processes that are inter-organizational.
3. **Information – (a) finding patterns of information through text and data mining; (b) structuring information via domain & quality models across stakeholders; and (c) organizing information flow to support building and validating material solutions.**
4. **Evaluation** – assuring quality of both product and process, and especially the tie between the two.
5. **Learning** – the integration of evaluations and other forms of feedback at the enterprise level (both PEO and SoS or FoS) into actionable improvements.

Current CEF work focuses on the **Information** dimension in support of Battle Command (BC) Capability Portfolio Management (CPM).

Information Dimension: Benefits

There are several benefits of capability & domain driven BC software design.

1.Traceability, and therefore validation, of multiple software systems and systems of systems is facilitated.

- Currently, traceability is missing and validation is reduced to verifying mission threads
- S &T opportunities are under appreciated because of insufficient mutual understanding between warfighter and software technologist

2.Composing system of systems to enable capabilities that none of the systems alone can enable will be better understood.

- Current capability documents provide a partial picture of how systems can or should fit together
- There is no common ground for reasoning about system composition.

3.Capability Portfolio Management across programs in a PEO and across PEOs will be facilitated.

The Information Dimension: Sources

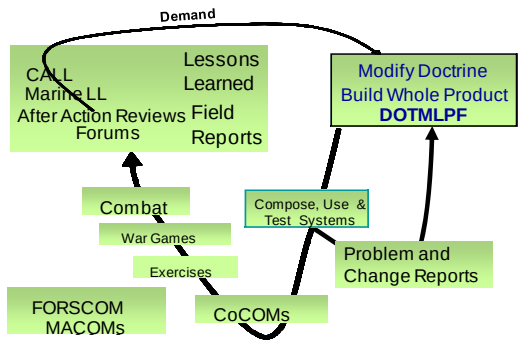
In order to represent the domains guiding capability driven software,

- sources of domain expertise and information have to be tapped
- processes for domain modeling must be established.

In the military, much of the expertise is written down in the form of

=> **1. Joint Capability Areas**

2. Concept Documents
3. Doctrine
4. Capability Documents (ORDs, ONS, ICDs, CDDs, CPDs…)
5. Information Support Plans (ISPs)
6. User Functional Descriptions
7. Problem and Trouble Reports
8. Shortfalls and Warfighter Outcomes
9. Exercise After Action Reviews, Independent Evaluation Results



Joint Capability Area Focus: Battle Command Capability 1

Command & Control

Organize
- Establish & maintain unity of effort w/ mission partners
  - Develop Trust
  - Estab & Cultivate Rel w Msn Partners
  - Estab & Cultivate Rel w Partner Orgs
- Structure organization to mission
  - Define structure
  - Assess Staff Capabilities
  - Delegate Authority
  - Identify Capabilities Needed
  - Integrate Capabilities
  - Estab Commanders' Expectations
- Foster organizational collaboration
  - Estab Collaboration Policies
  - Estab Collaborative Procedures

Understand
- Organize Information
- Develop Knowledge and Situational Awareness
- Share Knowledge and Situational Awareness

Planning
- Analyze problem
  - Analyze Guidance
  - Review Rule Set
  - Review Situation
  - Determine Need for Action
  - Prepare Estimates
- Apply situational understanding
  - Assess Available Capabilities
  - Evaluate Environment
  - Determine Vulnerabilities
  - Determine Opportunities
- Develop strategy
  - Determine Force Readiness
  - Determine Resources
  - Adapt Strategy
  - Align Strategy
  - Develop Assumptions
  - Develop Objectives
  - Determine End State
  - Review Existing Plans
- Develop courses of action
  - Understand Objectives
  - Develop Options
  - Establish Selection Criteria
- Analyze courses of action
  - War game courses of actions
  - Compare courses of actions

Decide
- Manage risk
  - Validate Targets
  - Formulate Crisis Assessment
  - Provide Friendly Force Combat Identification
  - Direct Consequence Management
- Select actions
  - Select course of action
  - Select Plan
  - Terminate
- Establish rule sets
- Establish intent and guidance
  - Establish Priorities
  - Establish Standards
  - Establish Rule Sets
- Intuit
  - Recognize Key Triggers
  - Modify Actions

Direct
- Communicate intent and guidance
  - Issue Estimates
  - Issue Priorities
  - Issue Rule Sets
  - Provide CONOPS
- Task
  - Synchronize Operations
  - Synchronize Execution across Phases
  - Issue Plans
  - Issue Orders
- Establish metrics
  - Establish Performance Measures
  - Establish Effectiveness Measures

Monitor
- Assess compliance with guidance
  - Assess Employment of Forces
  - Assess Manner of Employment
- Assess effects
  - Assess Battle Damage
  - Assess Effects of Deception Plan
  - Assess Munitions Effects
  - Assess Performance
  - Assess Re-Engagement Requirement
  - Assess Operational Effects of Strategic Communications
- Assess achievement of objectives
  - Assess guidance

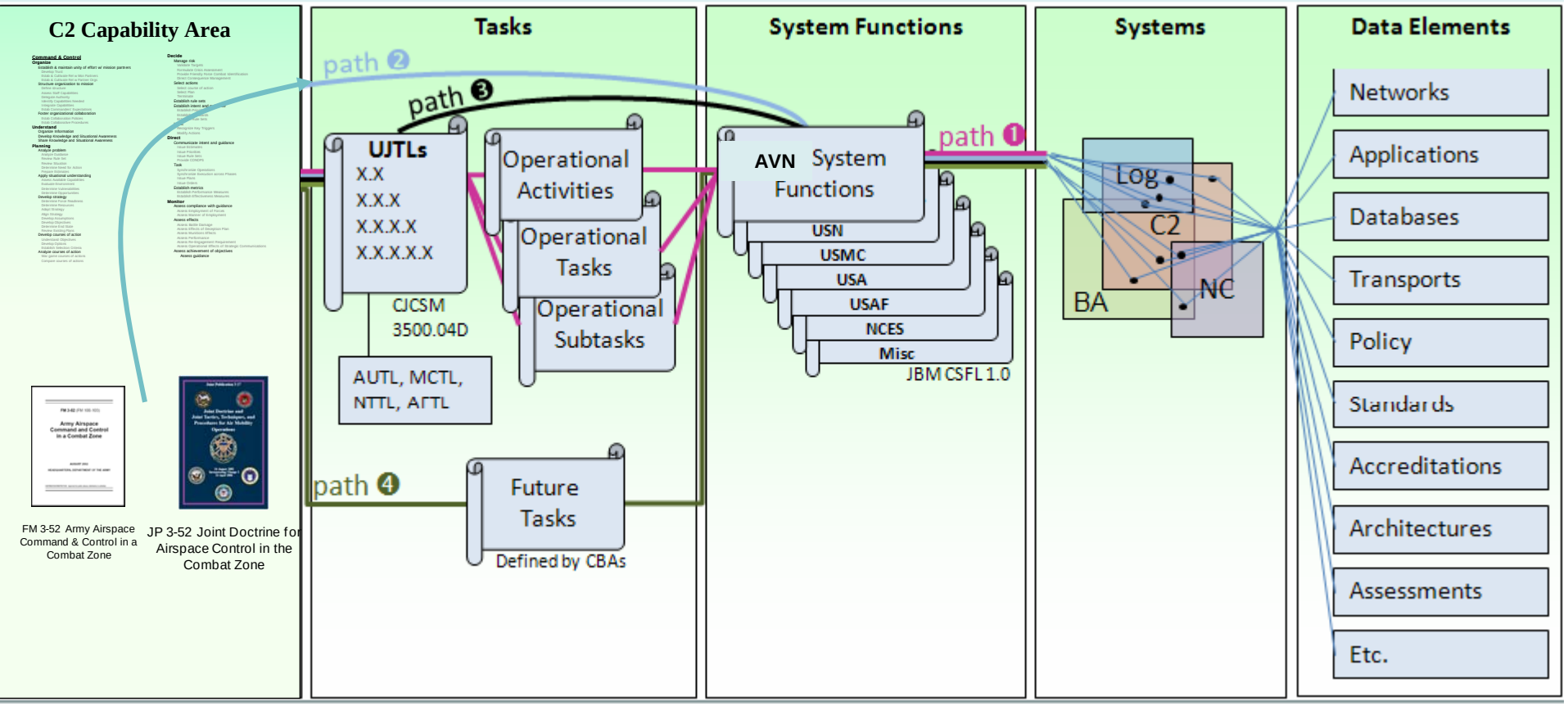
Joint Capability Area Focus: Battle Command Capability 2

- **Battlespace Awareness**
  - **Intel, Surveil, & Recon**
    - ISR Planning & Direction
      - Define & Prioritize Rqmts
      - Develop a Collection Strategy
      - Task & Monitor CPED Resources
      - Evaluation & Feedback
    - Collection
      - Signals
      - Imagery
      - Materials
      - Human
      - Open source
      - Direction
    - Processing / Exploitation (CNE)
      - Correlate
      - Convert
      - Exploit
    - Analysis & Production
      - Intel Prep of Opnl Environment
      - Intel Spt to Situational Understanding
      - Indications & Warnings
      - Intel Spt to Targeting, FP & IO
      - Battle Damage Assessment
      - Science & Technology
      - Counter Intelligence
    - ISR Dissemination
  - **Environment**
    - Collect
    - Analyze
    - Predict
    - Exploit

- **Net-Centric**
  - **Information Transport**
    - Switching and Routing
    - Wireless
    - Wired
  - **Enterprise Services**
    - Core Enterprise Services
      - Collaboration
      - Mediation
      - Discovery
      - Messaging
    - Information Sharing/Computing
      - Data Storage
      - Data Processing
      - COI Services
    - Position Navigation and Timing
  - **Net Management**
    - Optimized network functions & resources
    - Deployable, scalable & modular networks
    - Spectrum Management
    - Cyber Management
  - **Information Assurance**
    - Secure Information Exchange
      - Ensure Authorized Access
    - Protect Data and Networks
      - Monitor IA Status
      - Track User Actions
      - Prevent Network Attack
      - Protect Data from Modification
    - Respond to Attack / Event
      - Detect & Respond to Attacks
      - Detect & Respond to Event

USJFCOM J8

Capability to System Mapping:
Joint Common System Function List (JFCOM- JSIC)



- **Mapping systems to system functions enables traceability to Joint & Army-wide operational capabilities**
- **The Joint Common System Function List (JCSFL) is cumbersome & manually applied by JSFL experts.**
- ***Successful mapping may be facilitated by automated support that could leverage the JCSFL***
- **Engage with PEOs to evaluate current proposed JCSFL mappings & viability of automated support**
- **Proposed manual mappings include AMPS, DCGS, FBCB2, FCS, GCCS, JWARN, Prophet, SaaS, TAIS**

Capability to System Mapping:
Concept Maps & Domain Modeling

Both automated and interactive analyses will be performed on collections of documents chosen from each information source.

Automated content analysis will produce ***concept maps*** of selected information sources.

Concept maps will be ***interpreted and aligned*** to the extent possible.

The aim is to find conceptual links among maps of the information sources that will support ***domain modeling*** of BC contexts.

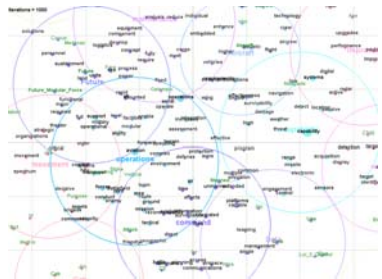
The BC context currently being investigated is Army Aviation.

The current focus is to align BC enabling systems as specified by PEO Aviation with planning capabilities as specified by TRADOC.

Methodology :
Content Analysis & Concept Maps

Semi-automated content analysis uses automated text analysis tools to identify recurring concepts & clusters of concepts:

- Concepts are synonyms of strongly related co-occurring terms identified in automatically generated affinity lists
- Concept Clusters are collections of co-occurring concepts
  - more strongly related to each other than to concepts in other clusters
  - named by automatic selection of the concept most strongly related to other concepts in the cluster

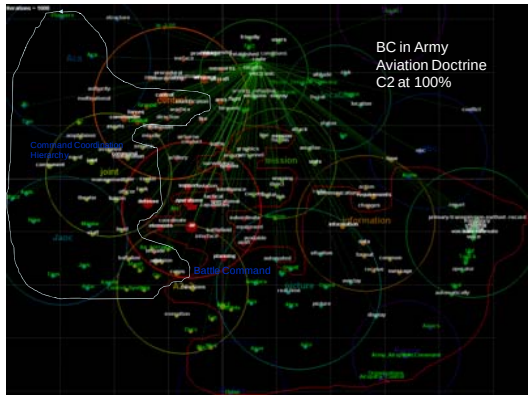


Concept Clusters are represented graphically as Venn diagrams.

- concepts labeling dots are in concept clusters represented as circles
- dots can be linked by lines whose brightness represents frequency of co-occurrence
- dots can appear in the overlap of two (or more) circles
- circle size based on distribution of concepts included in the circle (not importance)
  - brightness represents interconnectedness of concepts in the circle

Content Analyses and The Role of Interpretation

Map overlays can delimit groups of concepts from more than one concept cluster according to human interpretation, e.g., BC, BC enablers, helicopters



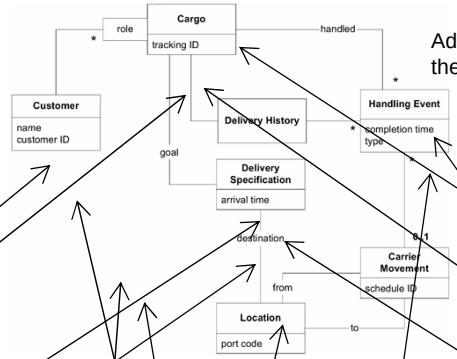
Interpretation also depends on posing and answering specific questions,

- **Question:** Are there concepts that trace back from documentation of BC software intensive systems to documentation of BC capabilities?
- **Traceability Potential:** **Route** and its role in BC planning is one such concept.

The maps shown require additional interpretation in collaboration with combatants, domain experts, requirements and capability developers and testers.

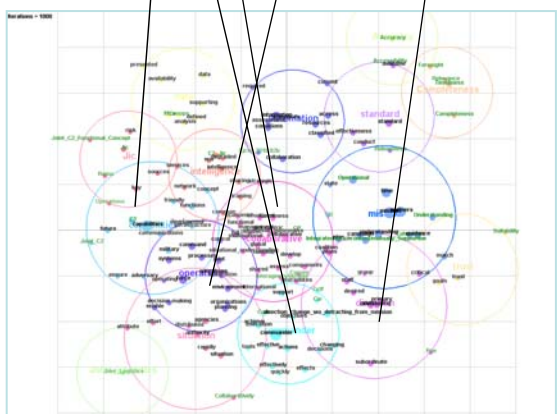
Aligning Concept Maps: On the Way to Domain Modeling

Shared Kernel (e.g., route)

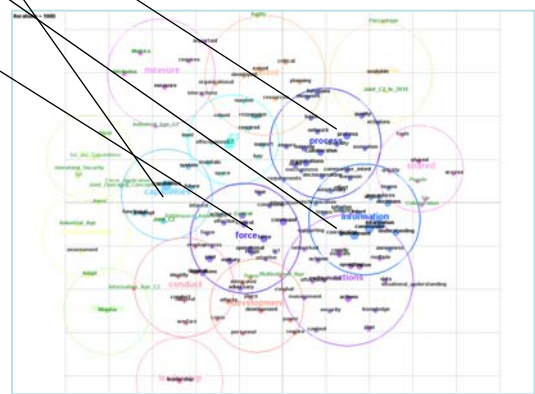


Adopted from Eric Evans, Domain Driven Design, Tackling Complexity in the Heart of Software, Addison Wesley Professional, 2003

Joint & Army Doctrine



ORDs, Capability Documents, UFDs & ISPs



ONS, AARs, Gaps, Shortfalls, Lessons Learned

Interpreting *Route* in Army Aviation Concept & Doctrine

Operations Concept (2008):

- *Route* plays a role in BC capabilities enabled by software intensive systems and is used in Army Aviation operations
- More specifically, *route* is used in C2 planning and to a lesser extent in other BC activities and BC enabling systems
- Though several specific helicopters are mentioned, *route* links to two – AH-64D & ARH-70

Operations Doctrine (2008 draft 2007):

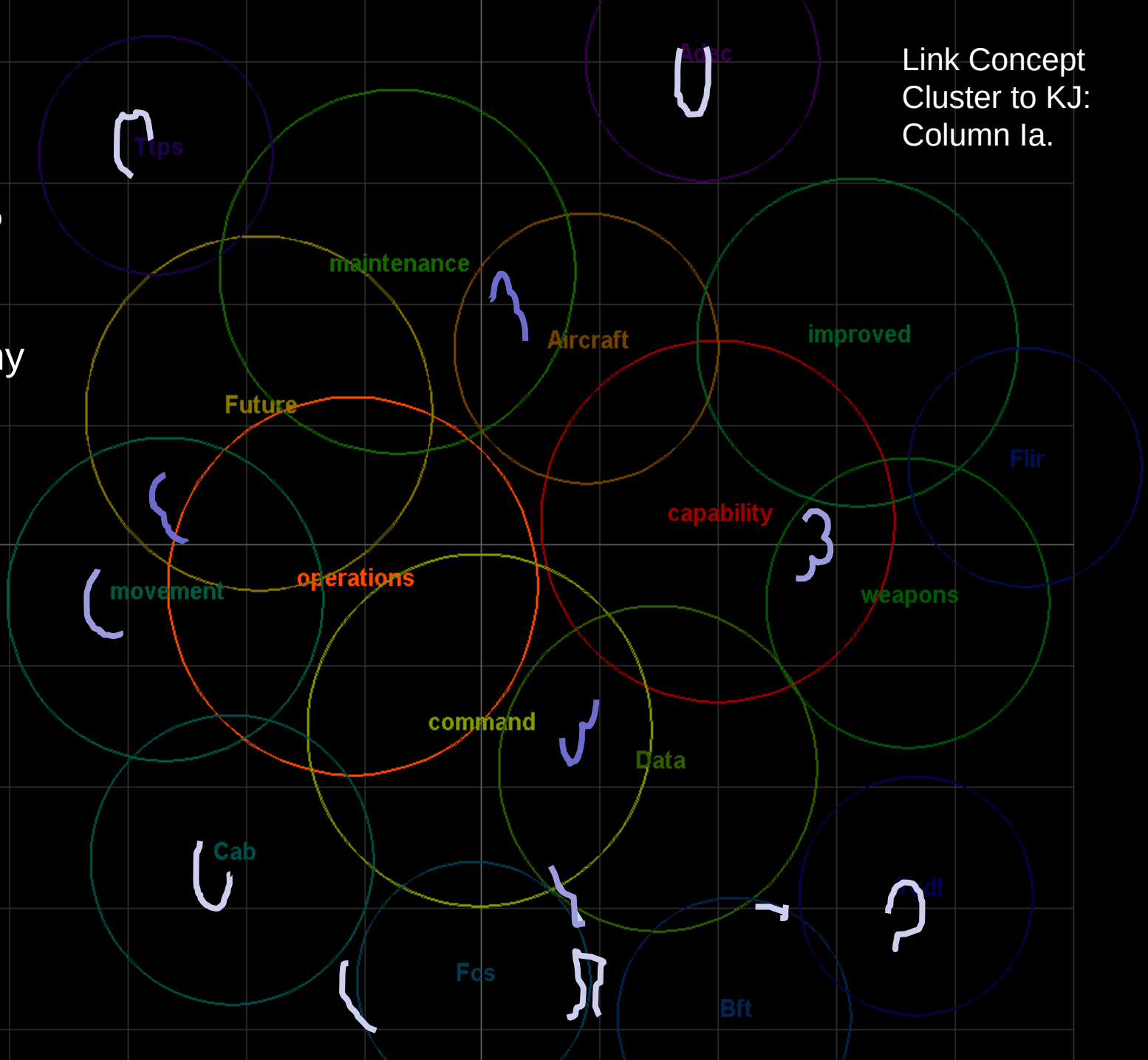
- *Route* plays a role in an Aircraft's flight & C2 operations, and also wrt planning
- *Route* & planning link to BC concepts but are somewhat separated from BC discussion
- *Route* links to discussion of specific helicopters – not the specific aircraft but concepts discussed with these, e.g., radar, infrared systems & visualizing

ons = 1000

Link Concept Cluster to KJ: Column Ia.

TP 525-7.15 (Concept Capability Plan for Army Aviation Operations 2015-2024):

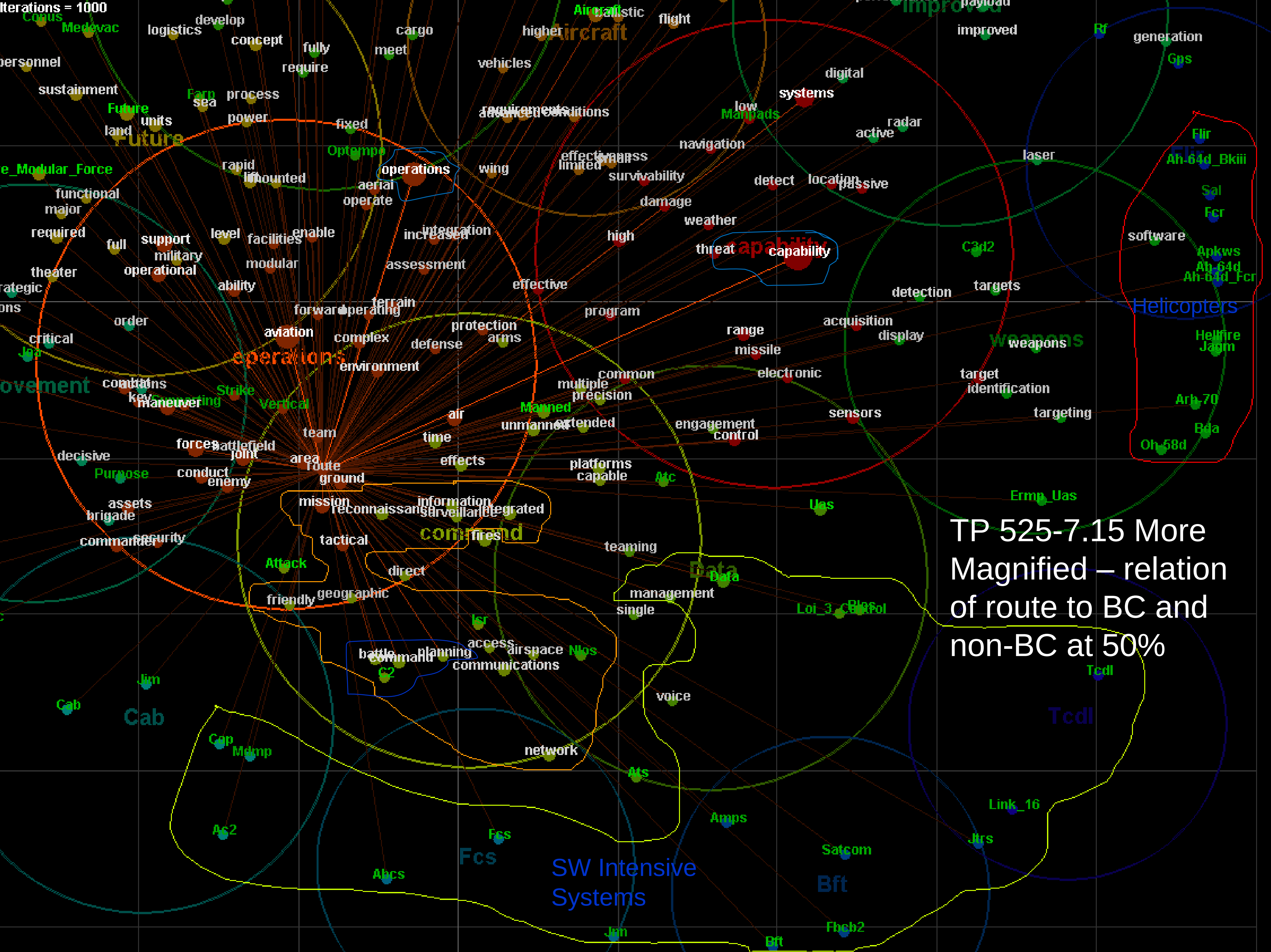
Concept Clusters



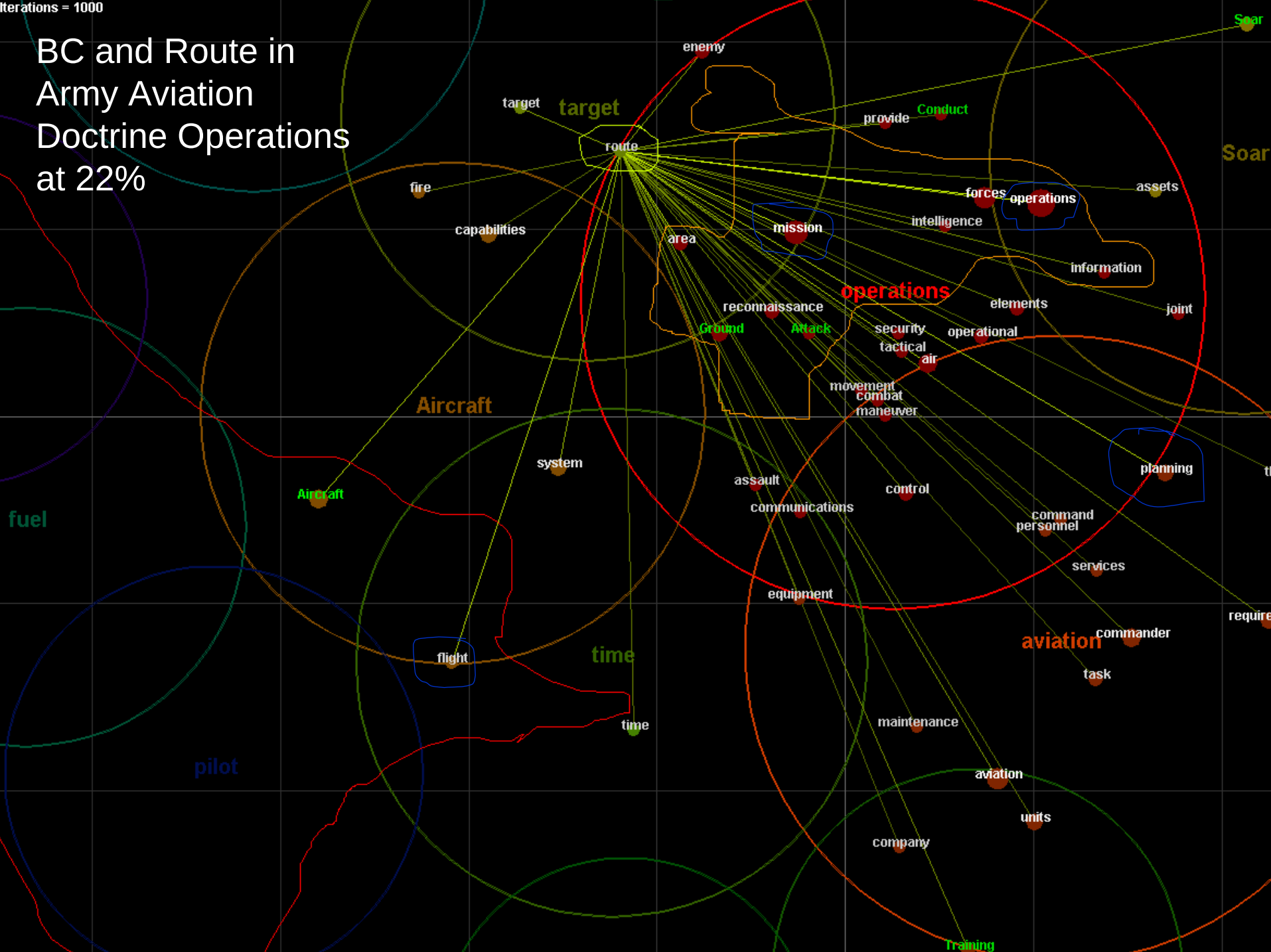
Core

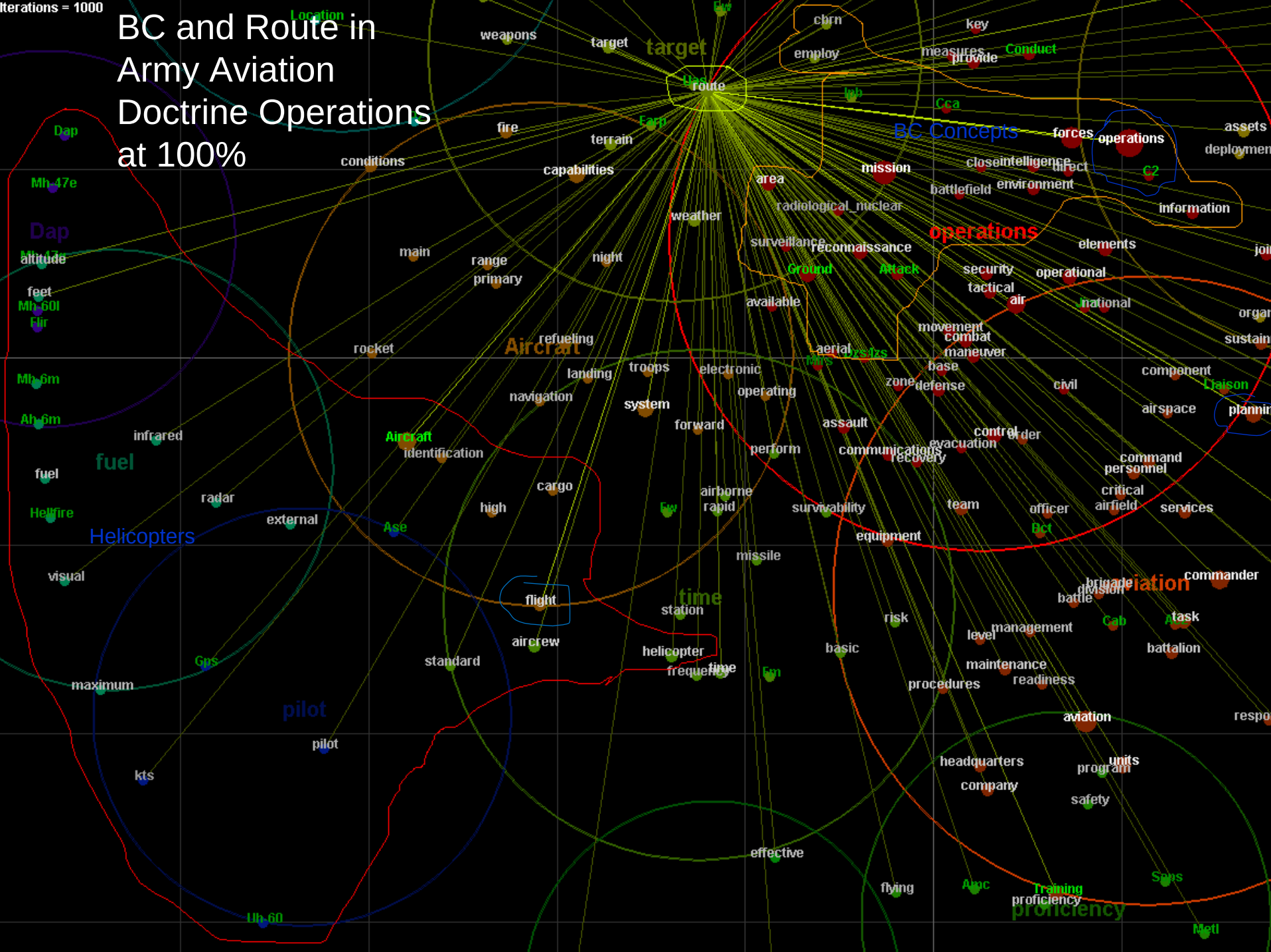
Near Core

Peripheral



TP 525-7.15 More Magnified – relation of route to BC and non-BC at 50%


Iterations = 1000
BC and Route in Army Aviation Doctrine Operations at 22%
Soar
enemy
target
target
provide
Conduct
route
Soar
fire
assets
forces
operations
capabilities
intelligence
mission
area
information
operations
reconnaissance
elements
joint
Ground
Attack
security
operational
tactical
air
movement
combat
maneuver
Aircraft
system
planning
assault
control
Aircraft
communications
fuel
command
personnel
services
equipment
require
commander
aviation
flight
time
task
time
maintenance
pilot
aviation
units
company
Training


Iterations = 1000
BC and Route in Army Aviation Doctrine Operations at 100%
BC Concepts
operations
target
route
Aircraft
fuel
Helicopters
pilot
time
proficiency
aviation
Dap
Mh-47e
Mh-60l
Flir
Mh-6m
Ah-6m
Hellfire
Gps
Uh-60
Location
weapons
target
Has
Cbrn
key
employ
measures
provide
Conduct
Iwb
Cca
fire
terrain
Farp
conditions
capabilities
forces
operations
assets
deployment
mission
closeintelligence
direct
C2
area
battlefield
environment
information
radiological_nuclear
weather
surveillance
reconnaissance
elements
Ground
Attack
security
operational
tactical
air
national
available
movement
combat
maneuver
base
component
Liaison
zone
defense
civil
airspace
planning
main
range
primary
night
altitude
feet
refueling
rocket
landing
troops
electronic
operating
navigation
system
forward
assault
control
evacuation
order
perform
communications
recovery
command
personnel
critical
airfield
services
infrared
identification
cargo
high
airborne
rapid
survivability
team
officer
Bct
equipment
radar
external
Ase
visual
missile
commander
brigade
division
battle
flight
station
risk
Cab
task
management
level
battalion
aircrew
helicopter
frequency
time
Fwn
basic
standard
maximum
maintenance
readiness
procedures
pilot
kts
headquarters
company
units
program
safety
effective
flying
Anac
Training
proficiency
Sans
Metl

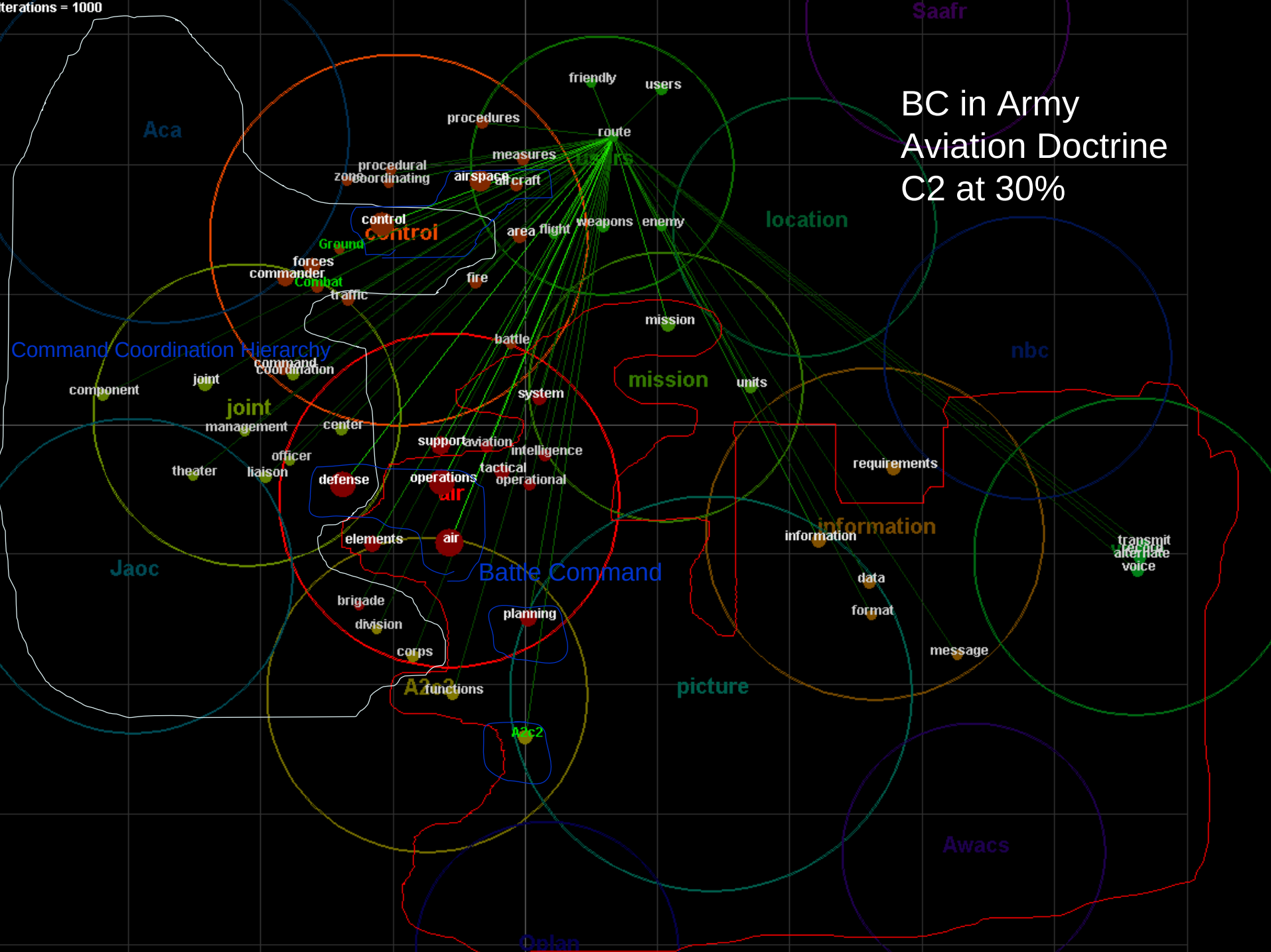
Interpreting *Route* in Army Aviation C2 Doctrine and Planning System DFD

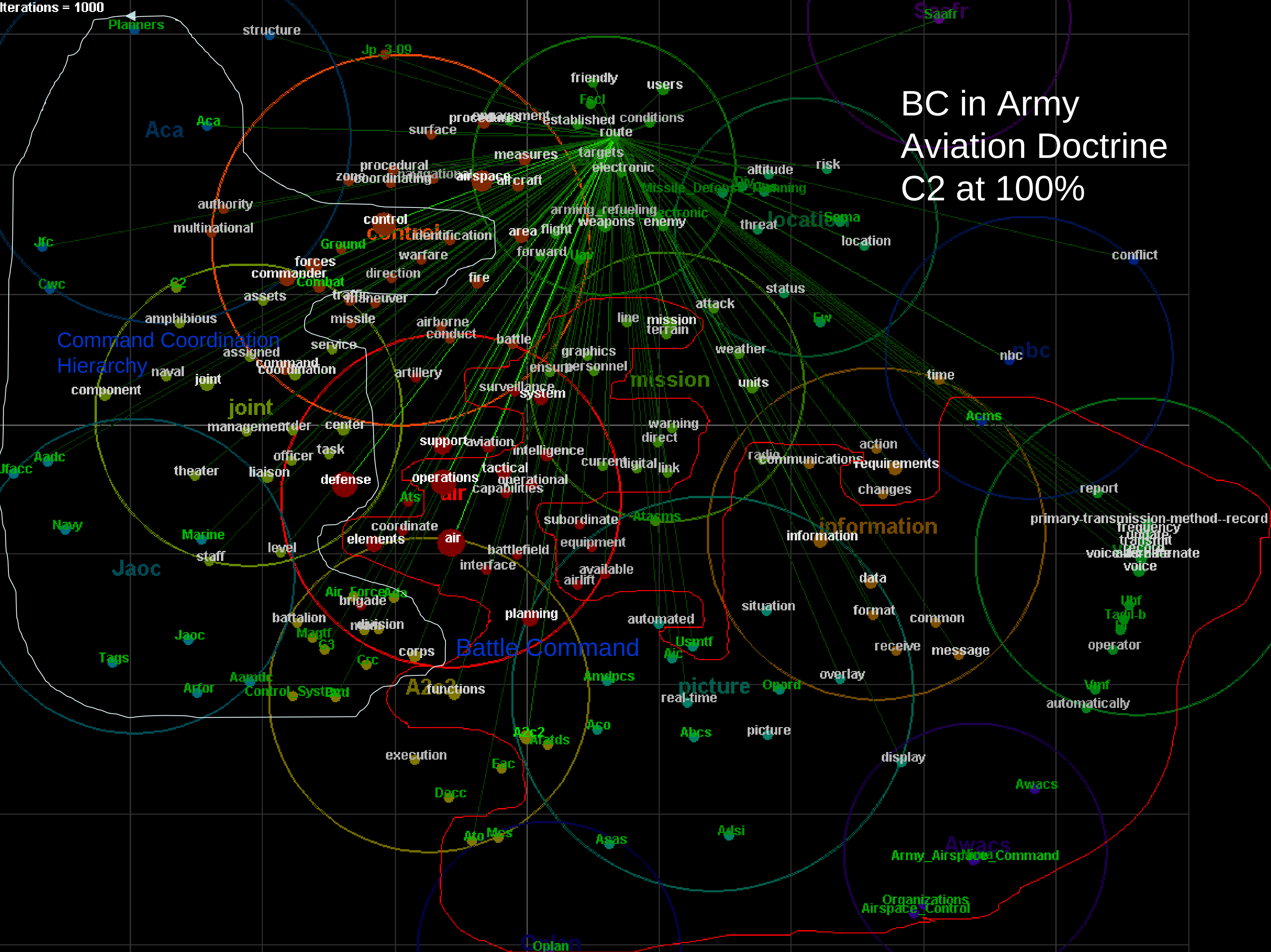
C2 Doctrine (2002):

- *Route* plays a role in air defense operations & control of the aircraft in airspace
- It is used in planning and A2C2 and to a lesser extent in the command coordination hierarchy
- Planning is within the BC overlay that includes concepts of BC & its enablers
- No mention of specific helicopters

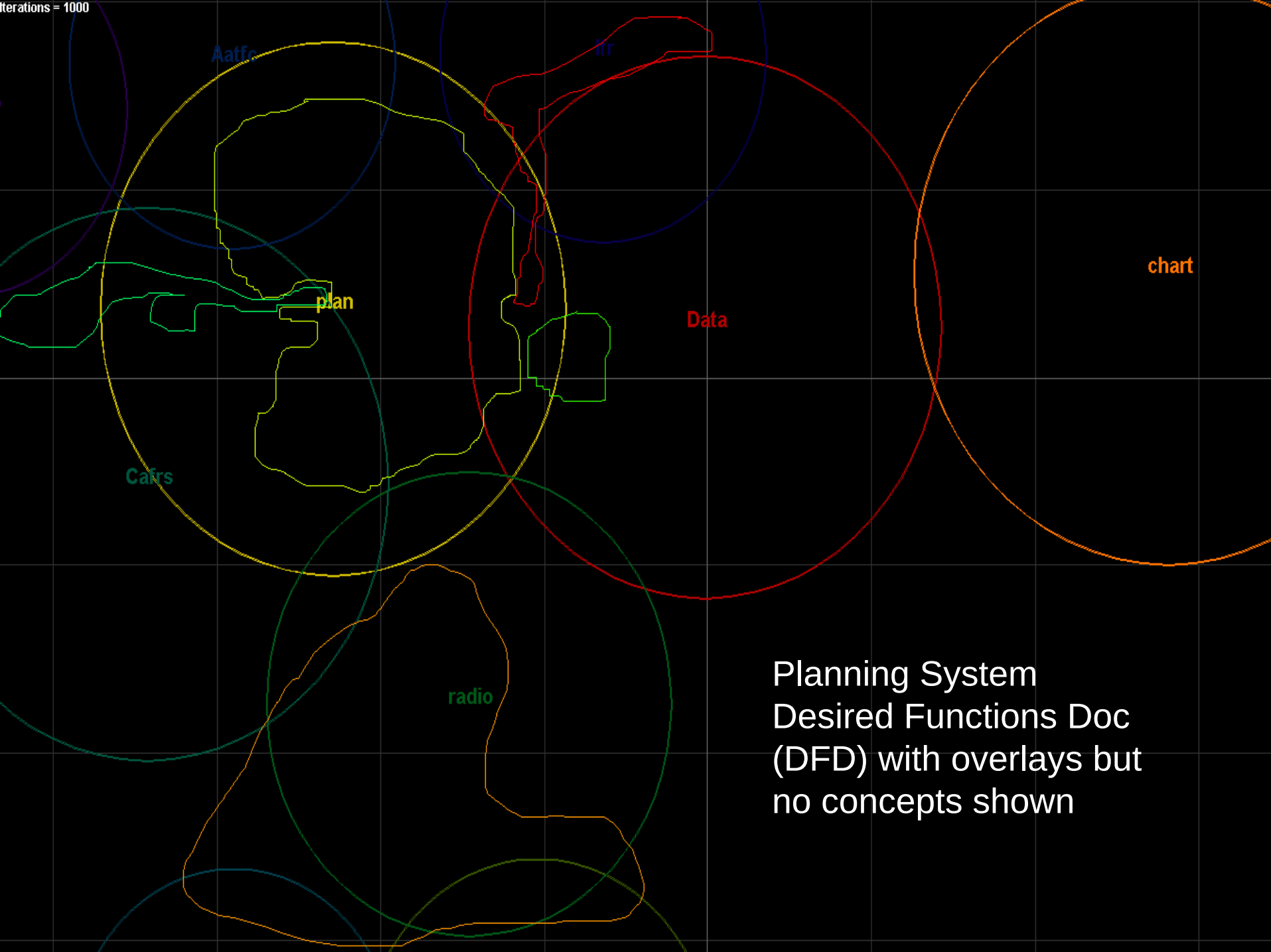
Planning System Desired Functions Document (2007)

- The focus is on *route's* role in planning capability & the aircraft's flight/mission
- Also in focus are information systems as capability enablers and Data as rendered in charts
- The overlay of BC concepts is contained in the Plan concept cluster, as is route
- Closely related overlays specifically refer to BC enabling (BCE) software intensive systems & helicopters

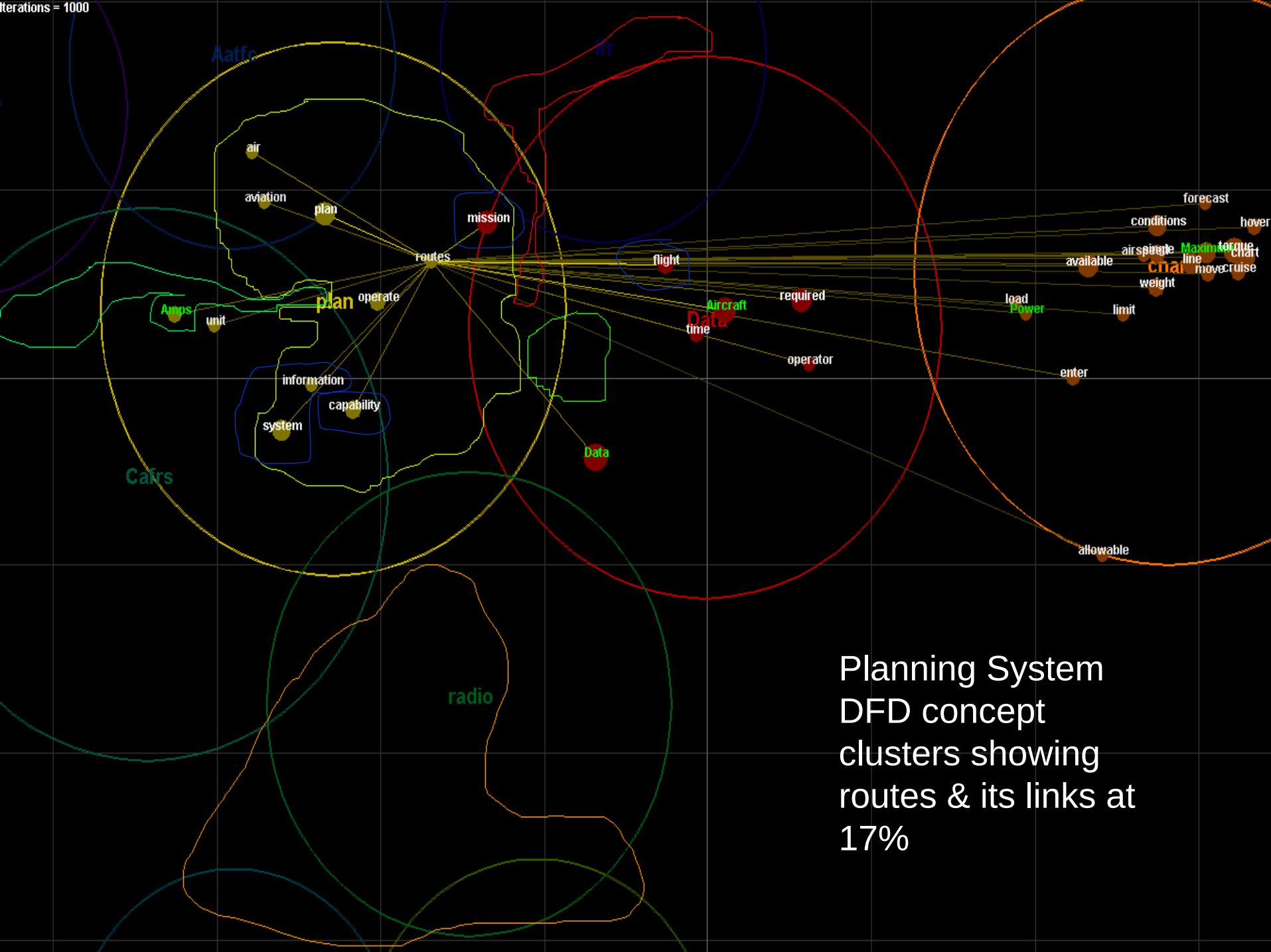

terations = 1000
BC in Army
Aviation Doctrine
C2 at 30%
Saafr
Aca
friendly
users
procedures
route
measures
procedural
coordinating
airspace
aircraft
control
control
area
flight
weapons
enemy
location
Ground
forces
commander
Combat
traffic
fire
mission
battle
Command Coordination Hierarchy
command
coordination
joint
component
joint
management
center
system
mission
units
nbc
support
aviation
intelligence
officer
theater
liaison
defense
operations
tactical
operational
air
requirements
information
information
transmit
alternate
voice
elements
air
Jaoc
Battle Command
data
format
brigade
division
corps
planning
message
A2c2
functions
picture
A2c2
Awacs
Oplan



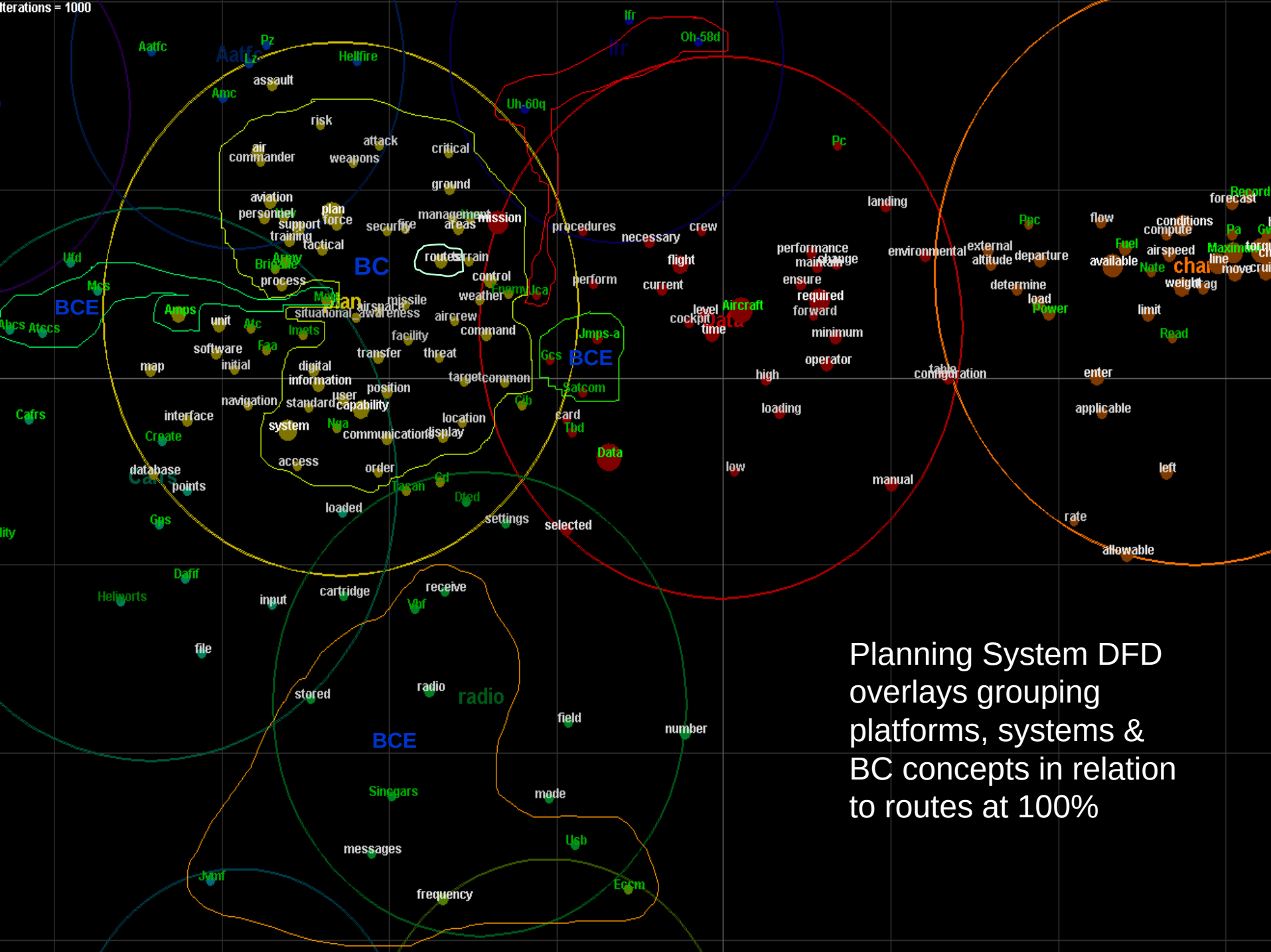
Iterations = 1000
BC in Army
Aviation Doctrine
C2 at 100%
Planners
structure
Jp_3-09
Saafr
friendly
users
Fscl
established
conditions
route
surface
measures
targets
electronic
procedural
coordinating
airspace
aircraft
Aca
authority
multinational
altitude
risk
Jfc
control
identification
area
flight
weapons
enemy
threat
location
Sema
Ground
warfare
forward
Uav
conflict
forces
commander
direction
Combat
fire
status
Cwc
C2
assets
maneuver
attack
amphibious
missile
airborne
conduct
line
mission
terrain
Ew
Command Coordination
Hierarchy
assigned
service
battle
graphics
weather
command
coordination
ensure
personnel
nbc
naval
joint
artillery
surveillance
system
mission
units
time
component
joint
Acms
management
order
center
warning
direct
support
aviation
intelligence
action
Aadc
task
officer
current
digital
link
radio
communications
requirements
Jfacc
theater
liaison
tactical
operational
defense
operations
capabilities
changes
report
Ats
air
primary-transmission-method--record
Navy
subordinate
Atacms
information
frequency
transmit
coordinate
equipment
voice
Marine
elements
air
battlefield
alternate
staff
level
Jaoc
interface
available
airlift
data
Air_Force
brigade
Ubf
situation
battalion
division
planning
automated
format
common
Tadil-b
Jaoc
Magtf
G3
Usmtf
receive
message
operator
Tags
corps
Battle Command
Aic
Crc
overlay
Aamdc
Amdpcs
Arfor
Control_System
Bcd
A2c2
functions
picture
Opord
Vmf
real-time
automatically
A2c2
Aratds
Aco
Abcs
picture
execution
display
Fac
Awacs
Dacc
Ato
Mcs
Asas
Adsi
Awacs
Army_Airspace_Command
Organizations
Airspace_Control
Oplan



Planning System
Desired Functions Doc
(DFD) with overlays but
no concepts shown



Planning System DFD concept clusters showing routes & its links at 17%



Planning System DFD overlays grouping platforms, systems & BC concepts in relation to routes at 100%

Analysis of Army Aviation BC Documentation:
Planning System STRs

Planning System Development STRs (2008):

•*Route* is thematic and consists of points created by a user in dialog with the software modules SAGE & AWE manipulating messages & files

•*Routes* are imported from files, created, selected and displayed

•Data changes and changing values occur and are linked to *route*

•All the above are implicated in errors

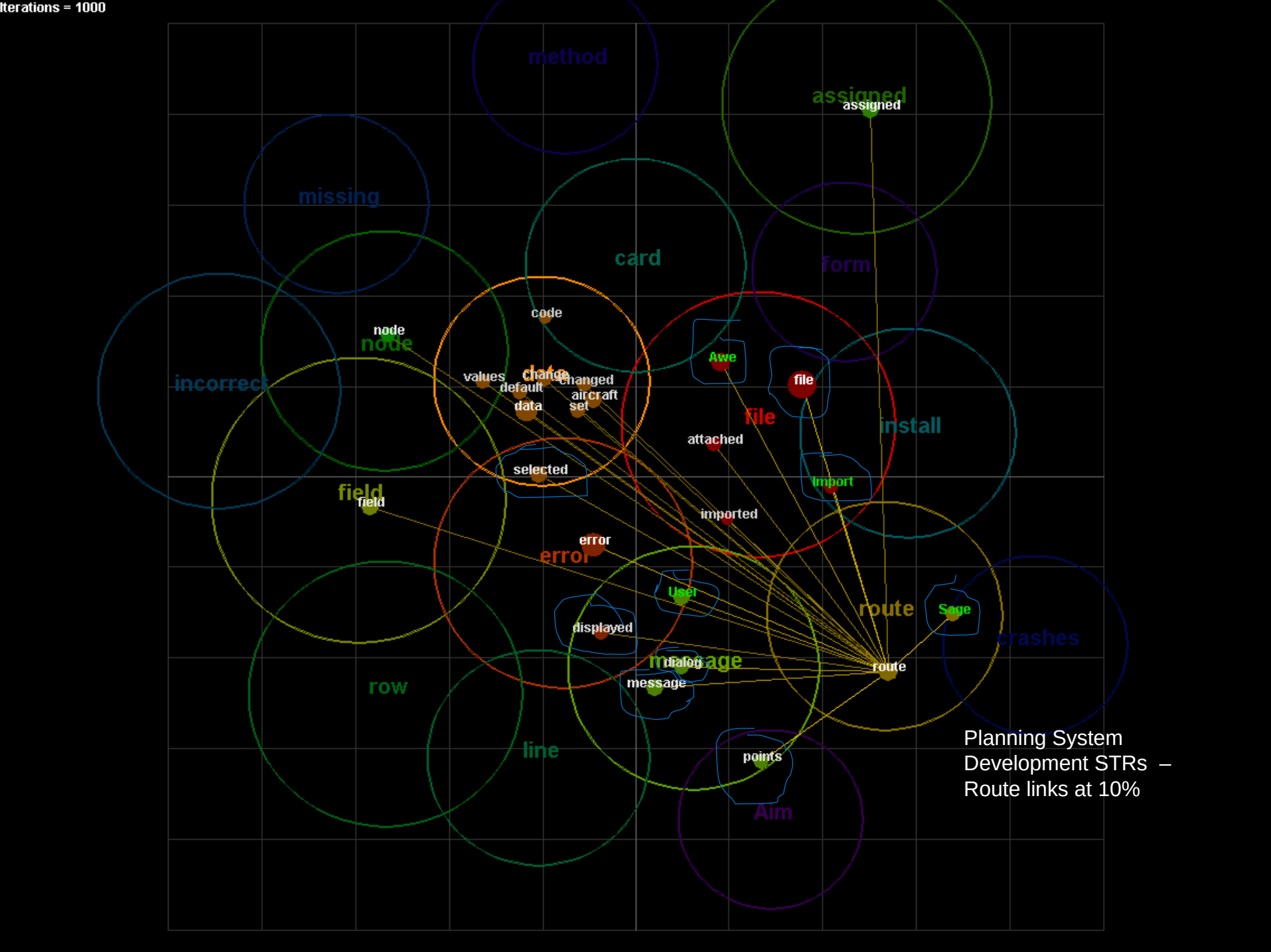
Planning System Post-Development STRs (2008):

•*Route* consists of points graphically displayed in dialog with SAGE, though change is associated with *route* not data

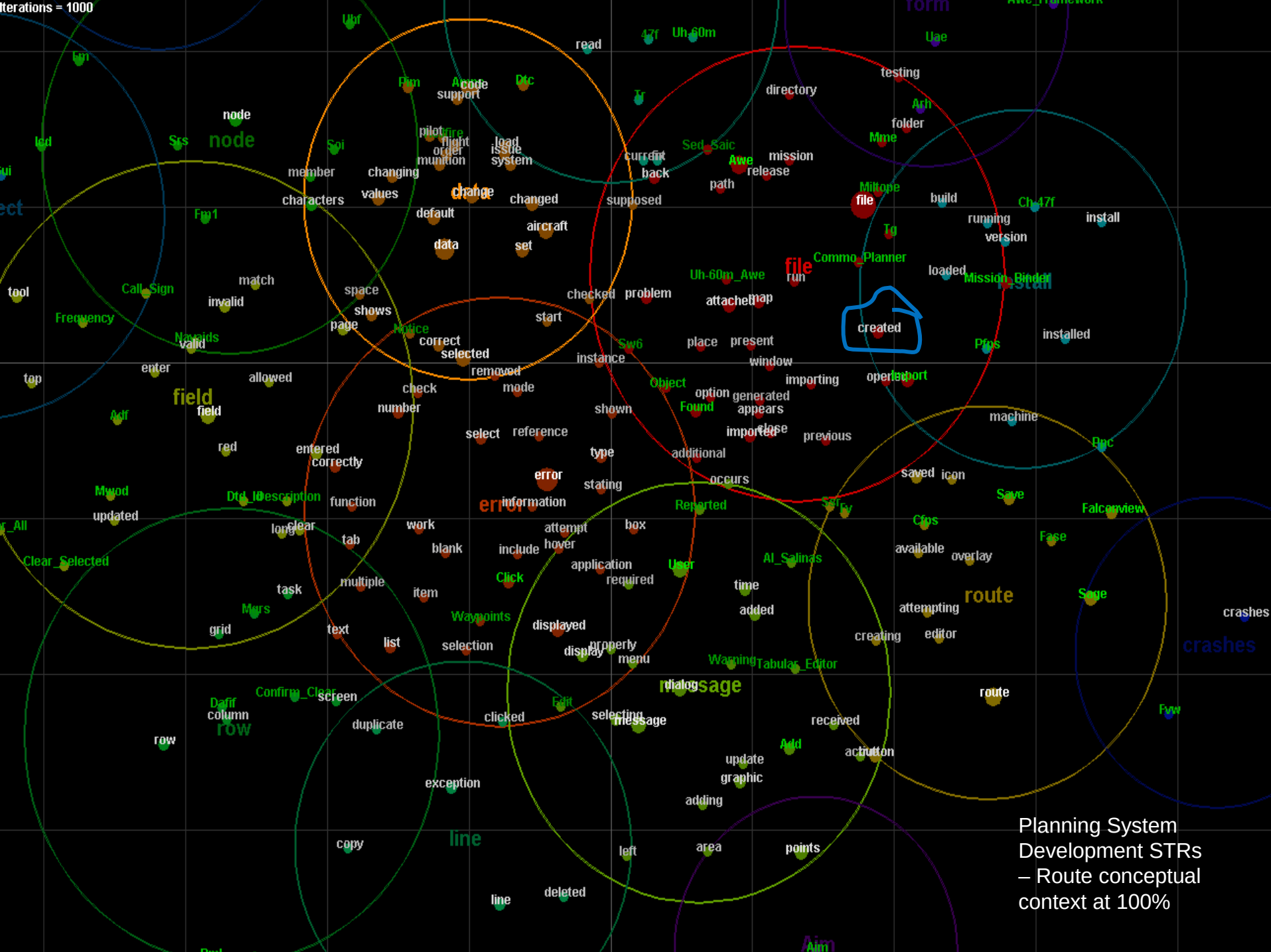
•Graphics and dialog are now thematic

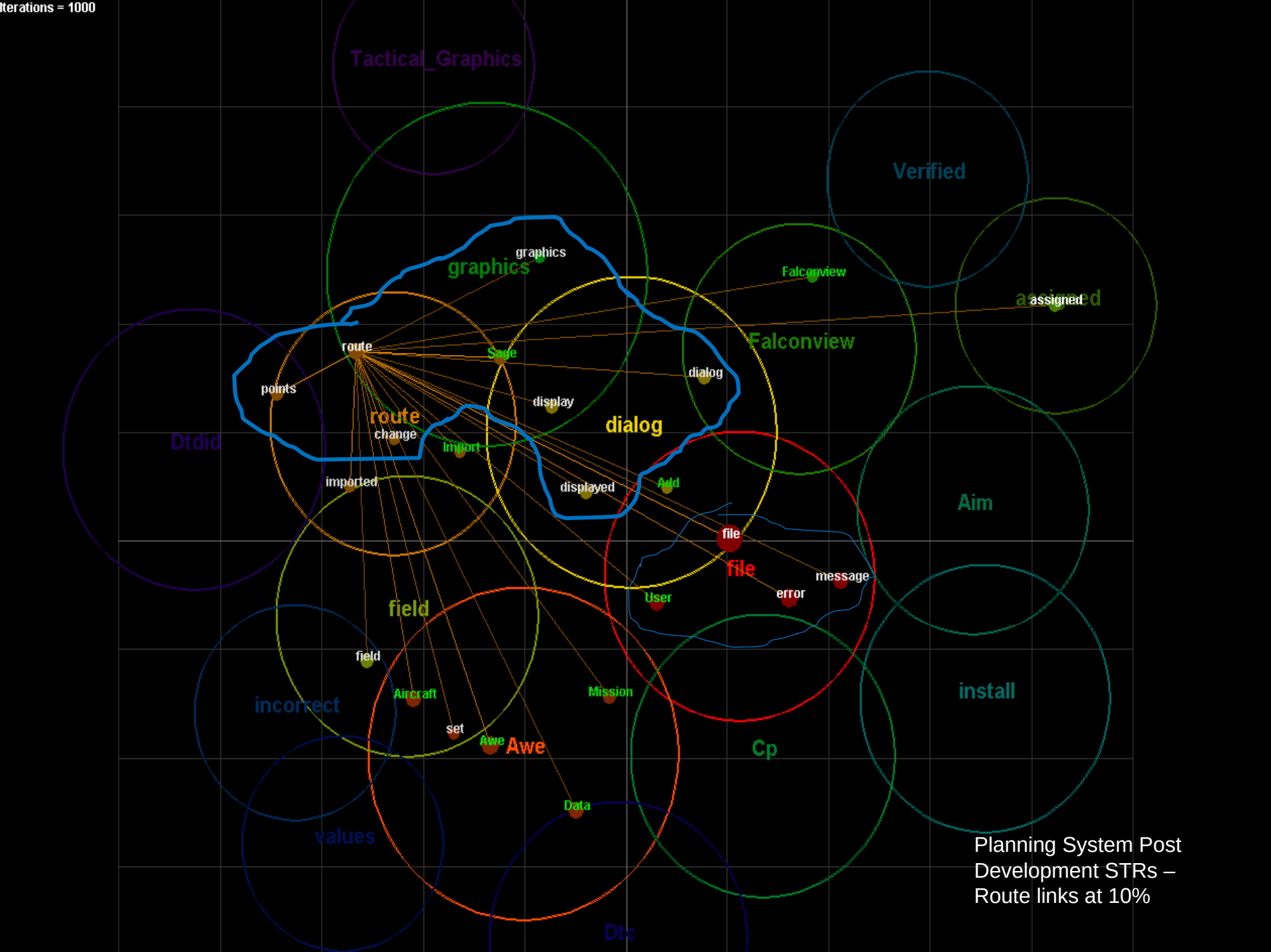
•File, message and user are most associated with error.

•Imported waypoints are now closely associated with *route* as is Mission Planning

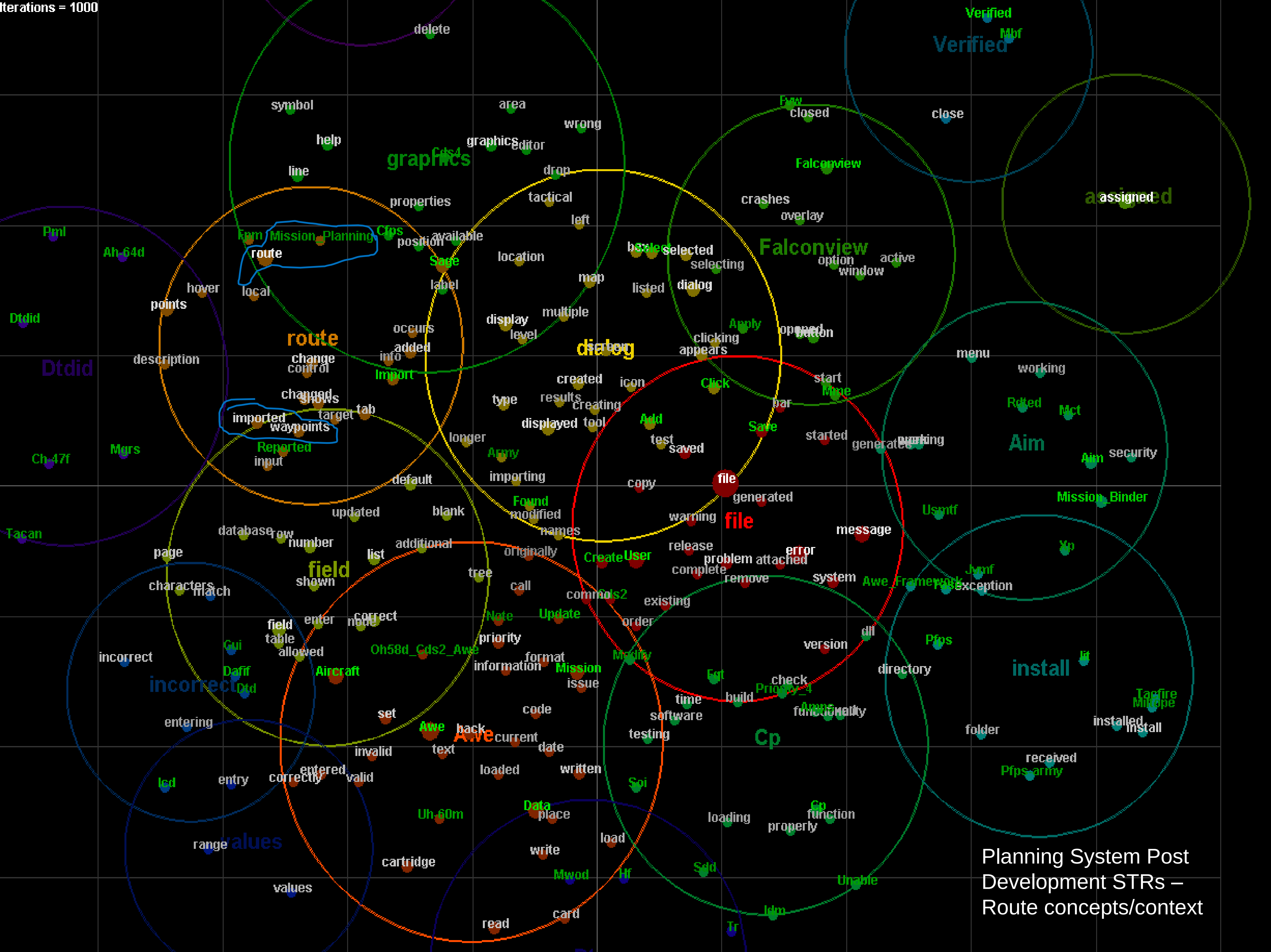


Planning System Development STRs – Route links at 10%


Iterations = 1000
Planning System Development STRs – Route conceptual context at 100%



Planning System Post Development STRs – Route links at 10%



Iterations = 1000
graphics
route
dialog
file
field
Falconview
Verified
assigned
Aim
install
Cp
Dtdid
incorrect
values
Awe
delete
symbol
area
wrong
help
line
properties
tactical
left
location
map
display
multiple
level
created
icon
Click
Add
Save
test
saved
copy
generated
warning
message
release
problem
error
attached
complete
remove
system
existing
order
version
directory
check
build
time
software
testing
loading
properly
function
Mission_Planning
points
hover
local
description
change
control
changed
shows
imported
waypoints
target
tab
Reported
input
default
updated
blank
database
row
number
list
additional
page
characters
match
shown
tree
call
field
table
allowed
enter
correct
priority
format
information
Aircraft
set
back
current
text
date
invalid
entered
correctly
valid
loaded
written
code
place
write
load
cartridge
read
card
entering
entry
range
closed
close
crashes
overlay
option
window
active
menu
working
security
Mission_Binder
received
installed
folder

Planning System Post Development STRs – Route concepts/context

Analysis of Army Aviation BC Documentation:
Planning System STRs– Route as Domain Concept

The Planning System STRs are not capability focused, and rather given to buttonology, but they do make contact with BC contexts and domains through route and user.

Route is a domain concept that needs to be represented via domain modeling of BC Aviation contexts informing software development, acquisition and testing.

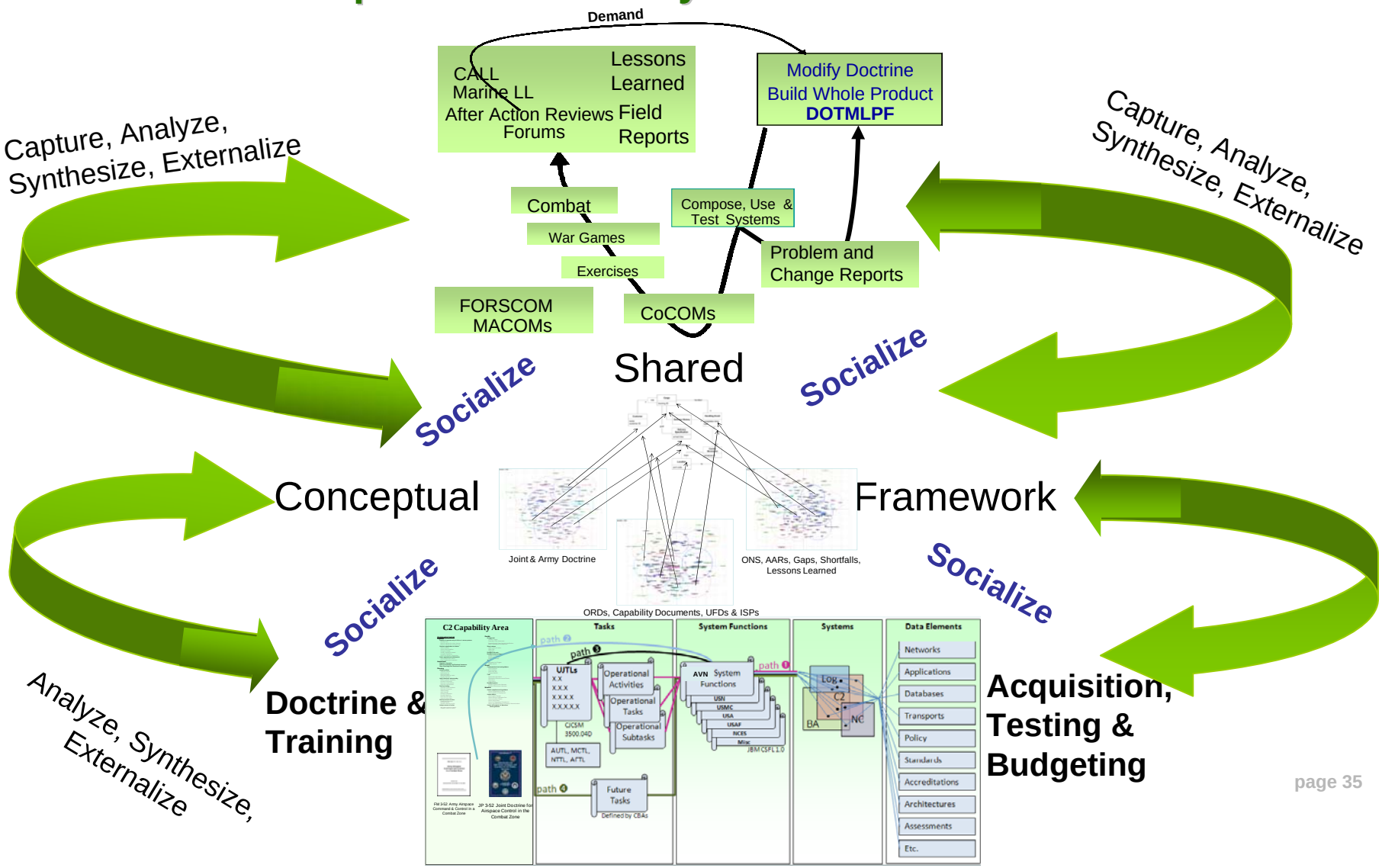
We have shown that TRADOC pamphlets, doctrine and DFDs could be utilized so that capability, domain and user centered testing has impact on prioritizing maintenance, refinement and evolution of systems.

We are planning meetings with combat and material developer domain experts to identify more concepts like *route* that will be sufficient for building

- **domain models in each sphere of expertise**
- **aligning the models in the Army Aviation BC context**

Summary:
Establishing Shared Conceptual Structures

Operational Military Information Flow



Thank you for your attention!

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