Applying a Work-Centred Exploratory Design Framework to Joint Fires Coordination

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Outline

- Complex Sociotechnical System Design Problems
- Concept Design Framework
- Work Analysis Framework
- Joint Fires Coordination Capability
- Knowledge Acquisition
- Analysis Methods & Results
- Identification of Design Requirements and Design Concepts
- Developing Options for Experimentation
- Concluding Remarks

Complex Sociotechnical System Design Problems

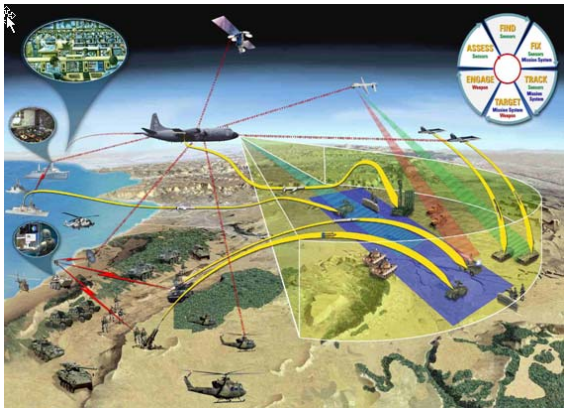
Current System

Command & Control in Submarine Control Room (VCS)

- Open, dynamic environments
- Variable and unpredictable work demands
- Uncertainty
- High risk, high stress
- Human expertise critical
- …

➢ **Need design methods that can cope with this complexity to support C2 concept development, exploration and testing**

Future System



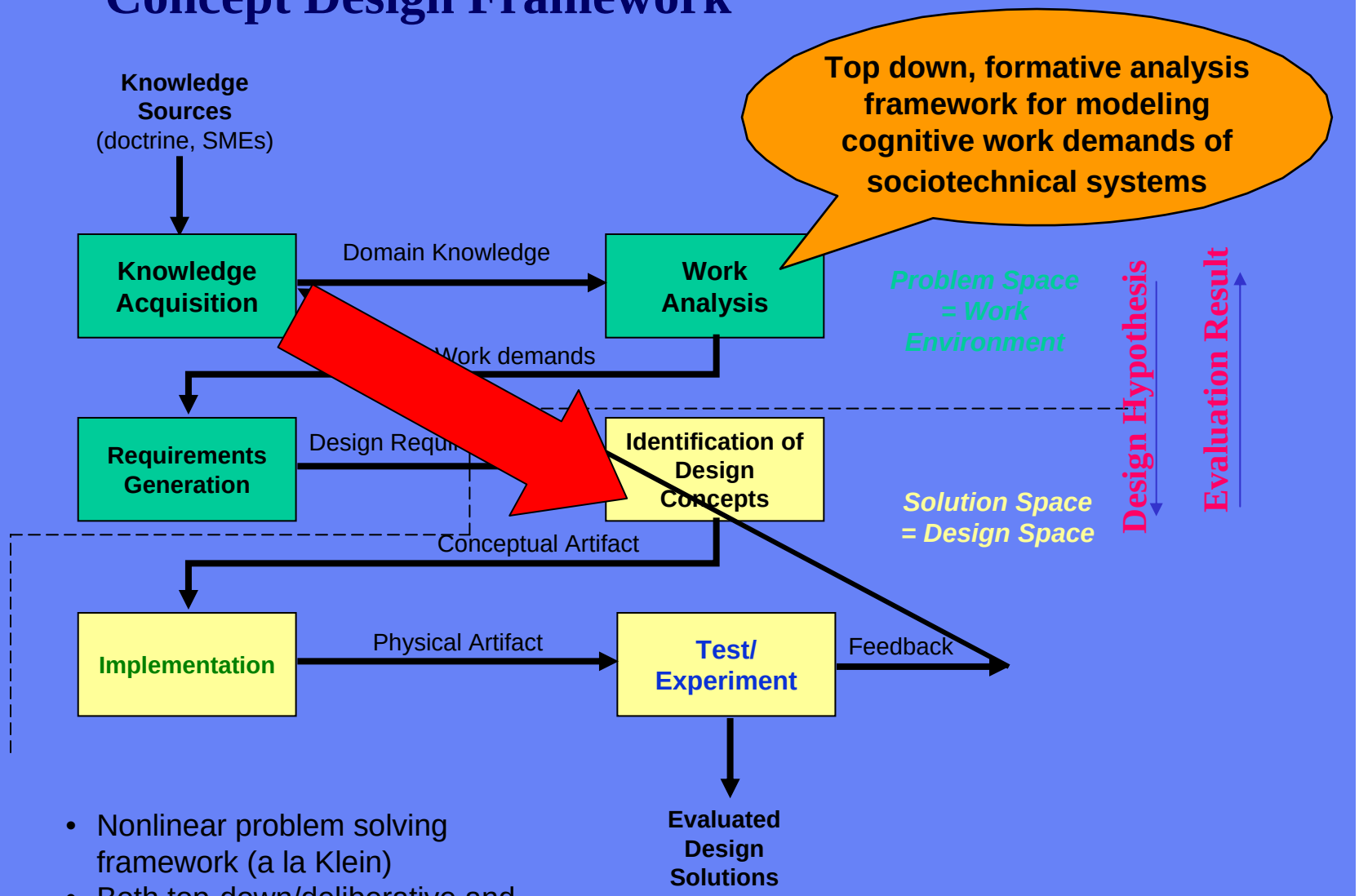
Joint Fires Coordination (JFC)

➢ **Need to provide design knowledge/outcomes about *technology*, *process* and *organizational structure* to structure, support, facilitate cognitve work**

➢ **Need methods for future systems**

- Initial system concept is only an envisioned one
- May be no close current analogue for that future capability
- Current system experts & system operators (if they exist) are current

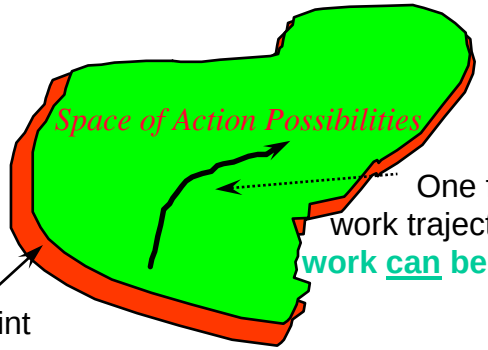
Concept Design Framework



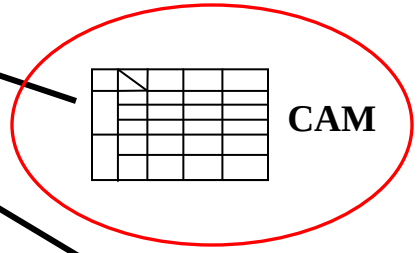
- Nonlinear problem solving framework (a la Klein)
- Both top-down/deliberative and bottom-up/serendipitous design strategies can be employed
- Exploratory prototyping
- Experimentation (e.g., HIL)

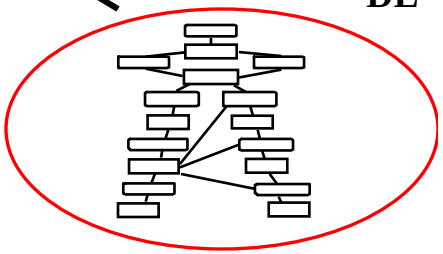
Design Requirement: What is needed? (solution-independent)
Design Concept: A potential solution

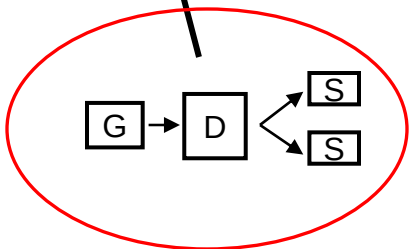
Work Analysis Framework: Emphasis on Formative Approach of Cognitive Work Analysis (CWA)



Phases of CWA	Kinds of Work Constraints	Modeling Tools
Work Domain Analysis (WDA)	Purpose and affordance structure of work domain	Abstraction-decomposition space
Activity Analysis (Work Org A + ConTA)	Work organization. Goals, decisions, cognitive transformations	Contextual Activity Matrix Decision ladders
Strategies Analysis (StratA)	Ways that control tasks can be executed	Information Flow Maps, Tables, GDS Flow Charts
Social Organisation and Cooperation Analysis (SOCA)	Who carries out work and how it is shared	Annotations of other models
Competencies Analysis (CA)	Kinds of mental processing supported	Skills, Rules and Knowledge models







Design of a Future Joint Fires Coordination (JFC) Capability

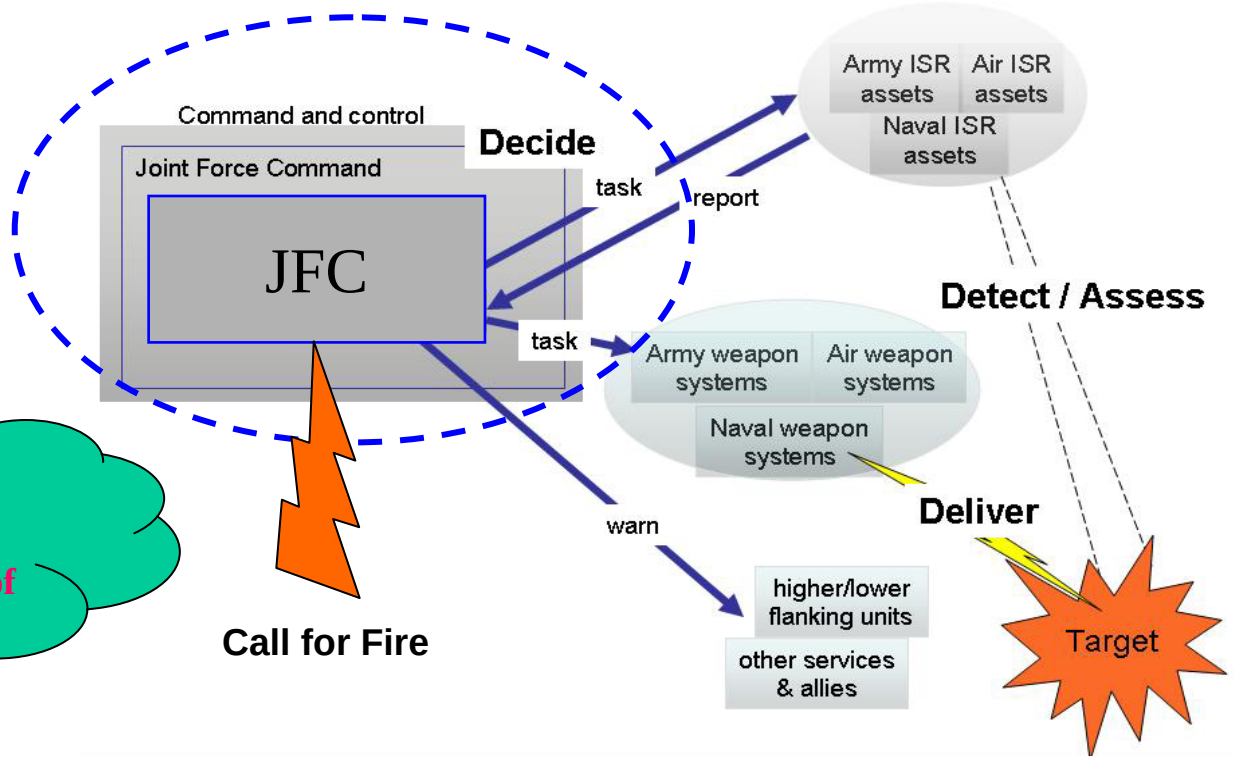
Aim: Identify design requirements and propose design concepts for a future operational level Canadian Forces **JFC** capability (**JFCC**).

With a JFC capability:

- A spotter, observer or other (land, sea or air based) will be able to request calls for fire on emerging and/or time sensitive targets
- JFC will designate and prioritize a target for engagement by the most appropriate weapon system available within the joint force

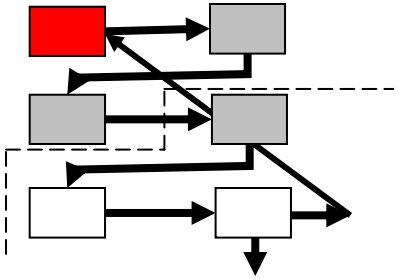
JFC Roles

- Pre-planned targets
- Mission support
- Emerging targets
- Time sensitive targets



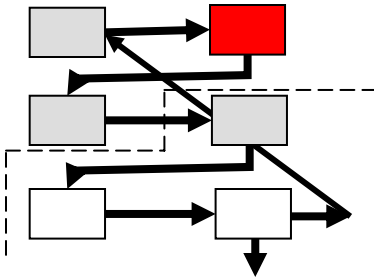
Presentation will look principally at appln. & results of first 3 phases of CWA

Knowledge Acquisition



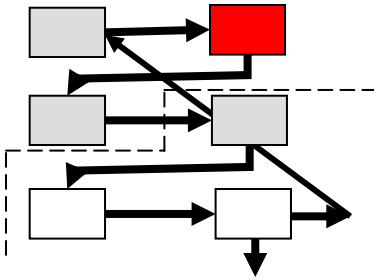
- **Reviewed Relevant Literature**
  - 15 CF doctrine documents (e.g., Firepower, Field Artillery, Close Air Support, Naval Gun Support, …)
  - 4 U.S. doctrine documents (e.g., Joint Fire Support, Joint Targeting)
- **Observed battle phase of an artillery planning exercise at CFB Gagetown**
  - Simulated setting, brigade and division levels
- **Six sets of SME Sessions (1-2 days each), incl.**
  - Surveillance and Target Acquisition training instructors
  - Major (Army; Artillery Officer, TF-Kandahar Fire Support Officer)
  - Major (RC-South, HQ Chief Joint Fires and Targeting)
  - Semi-structured interview sessions to support the specific analysis methods employed

Work Analysis: Specific Analyses



- **Augmented Cognitive Work Analysis (CWA)**
  - Mission and Organizational Analysis
  - Work Domain Analysis (WDA)
  - Control Task Analysis (ConTA)
  - Strategies Analysis
  - Goal Directed Task Analysis (GDTA)

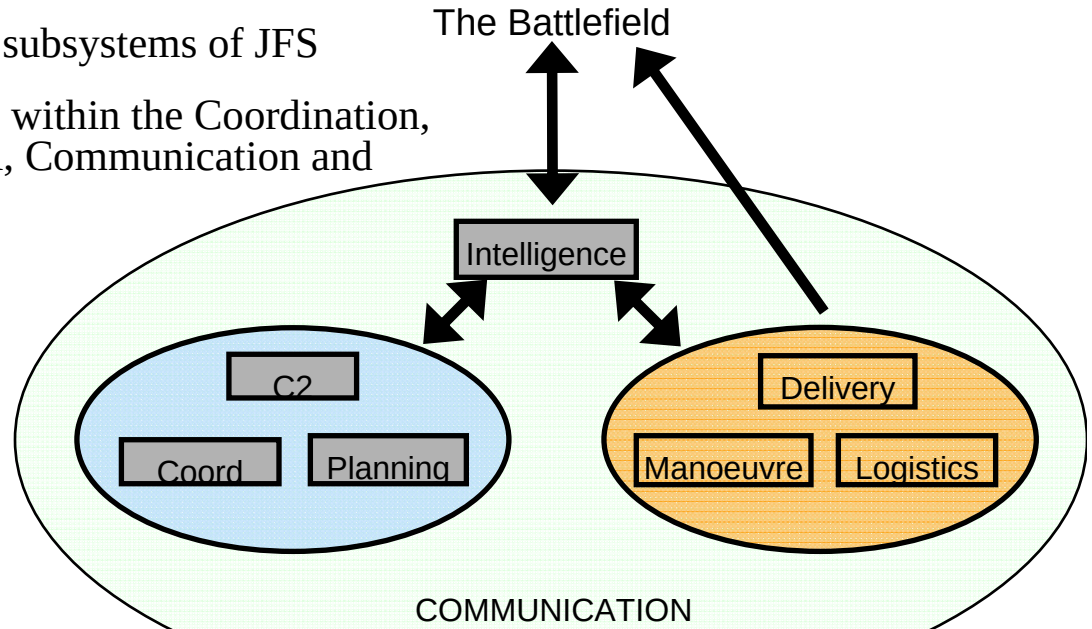
Mission and Organizational Analysis (MOA): Establishing the JFC System Boundary



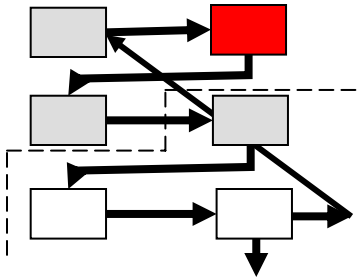
Joint Fires Support (JFS): "*Fire support is the collective and coordinated use of the fire of land and sea based indirect fire systems, armed aircraft, offensive information operations (IO) and non-lethal munitions against ground targets to support land combat operations at both the operational and tactical levels" (Firepower, 1998).*

The 'to-be' JFC is to be part of the broader JFS system

- Conducted a *mission and organizational analysis* of JFS to help establish JFC system boundary
- Identified 8 functionally distinct subsystems of JFS
- JFC primarily includes functions within the Coordination, Planning, Command and Control, Communication and Intelligence subsystems of JFS



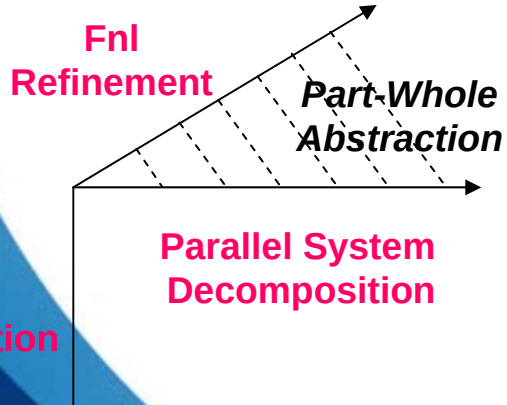
Work Domain Analysis (WDA)



Purpose: Model JFS system's functional and decompositional structure in an event-independent manner

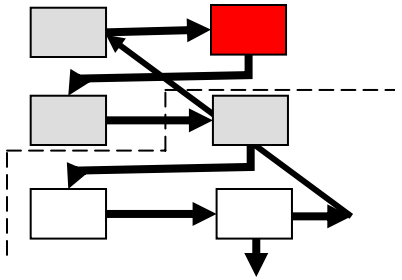
Method: Build a *modified* Abstraction Decomposition Space (ADS) of JFS

– Over 500 elements in final ADS

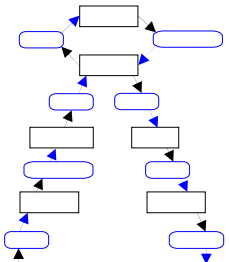


Abstraction Hierarchy Level	Definition	Example from the ADS
Functional Purposes	Purpose of the work system and indications of performance	Continually prioritize and plan fires that will put into effect Commander's Intent and optimize resource allocation
Abstract Functions	Underlying laws, principles, constraints, values and priorities of the work system	Maximize probability of achieving desired effect
Purpose-Related Functions	Processes by which Abstract Functions are carried out – found it helpful to use both types of part-whole abstraction in this level	Evaluate weapon capabilities and limitations; Evaluate effect of situational factors
Object-Related Processes	Capabilities and limitations related to achievement of Purpose-Related Functions	Planning support systems
Physical Objects	Rather than describe the physical appearance and location of equipment, as is typical at this level of the ADS (for 'as-is' systems), analysis provided an inventory of example objects and/or inputs used to meet	Weapon effectiveness table

Control Task Analysis (ConTA)



- **Purpose**: Decompose JFC into critical work functions relevant to JFC; model the cognitive information processing and resulting knowledge states of the control tasks involved; determine *what* needs to be done in the JFC work domain
- **Method**: Identification of work functions from WDA; Rasmussen's Decision Ladder (DL)



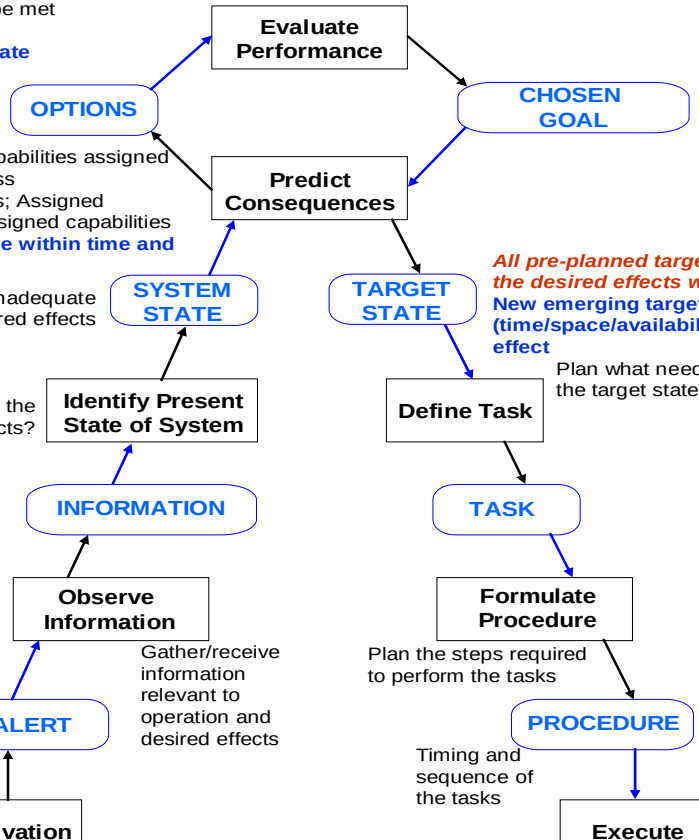
Target Type	Work Function
Pre-planned	Target Development and Selection
Pre-planned, Emerging	Capabilities Analysis
Pre-planned, Emerging	Force Assignment
Emerging	Process (Vet and Validate) Emerging Targets
Pre-planned (Mission Support)	Force Assignment for Mission Support
All	Outcome Assessment
All	Coordination of Components to Synchronize Actions
All	Management of JFC

ConTA – DL in Graphical Form
Work Function: Capabilities Analysis

Goals: Match capabilities to targets (on JPTL or emerging) to achieve desired effects in the most efficient and effective manner (***red*** – pre-planned target only; **blue** – emerging target only; black – all target types)

Are the selected capabilities realistic (i.e., is the required capability organic (available within our authority/organization); **is it within reach [time and space] to affect the emerging time-sensitive target)?** If not, is the capability available through other organizations?
What is the likelihood of achieving the desired effect with each capability?

d, delete and/or modify capabilities for each target
d or modify ranking of effectiveness and efficiency of
pabilities for achieving desired effect
rward target(s) to higher levels if capabilities cannot be met
current authority/organization
quest capabilities from other units more appropriate
sed on time and space positioning



Predict Consequences: Cannot complete force assignment process because capabilities have not been assigned to the necessary targets; Cannot complete force assignment process because capabilities have not been assigned appropriately given required effect, **availability and time constraints;** Failure to include ***all*** joint capabilities in the capabilities analysis (e.g., action by a manoeuvre force may create the desired effect(s))

Capabilities assigned match the desired effects; Capabilities assigned
ed appropriately based on efficiency and effectiveness
e: Assigned capabilities do not provide desired effects; Assigned
ies lead to unacceptable 2nd or 3rd order effects; Assigned capabilities
ealistic (i.e., not available within the CF; **not available within time and**
constraints)

Targets not matched with capabilities or inadequate matching to reach desired effects

All pre-planned targets are matched to capabilities that will achieve the desired effects with efficiency and effectiveness ranking;
New emerging targets are matched to realistic (time/space/availability) capabilities that will achieve the desired effect

Plan what needs to be done to bring the system to the target state

Are targets matched to capabilities that will meet the desired effects?

ION:
ed objectives and desired effects; **Available**
ystem-level capabilities (e.g., probability of
speed); ORBAT;
evable through use of **available** system-level
(provided through experience, military
s, technical manuals); Collateral damage
Time constraints; Information about the
size, status (dynamic, stationary), **location,**
time-sensitivity (from INTREPs, INTSUMS,
EPs, SITREPs); Information about target
es (e.g., nodal system analysis)

Tasks: Risk assessment (e.g., risk to mission success, collateral damage, fratricide, risk of not achieving desired effect, risk of unintended effects); Develop full range of capability options (including kinetic, non-kinteic, cominations) available to the commander ***(unconstrained)*** as they apply to targets; Specify capabilities through documentation (e.g., target folders); Send capability request to appropriate level of authority when required; Munitions Effect Assessment (predicting damage weapons can inflict against various types of targets); Weigh the relative effectiveness and efficiency of the capabilities as they apply to target vulnerabilities and the desired effects; Consider effect of capability selection as it shapes other planning considerations such as theatre logistics; **Consider capabilities relevant to circumstance of emerging target;** End the capability analysis when deemed appropriate

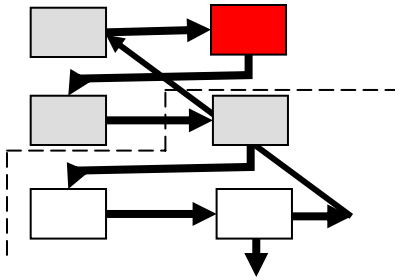
Gather/receive information relevant to operation and desired effects

Plan the steps required to perform the tasks

Approved JPTL;
Vetted and validated emerging target(s) (intelligence re: call for fire)

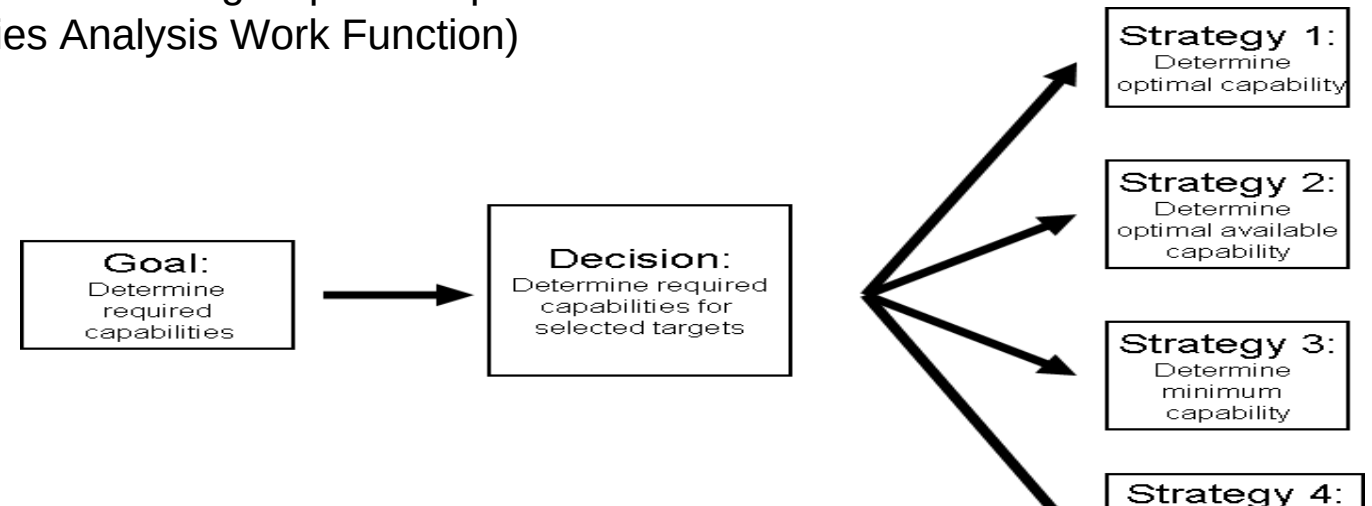
Timing and sequence of the tasks

Strategies Analysis (StratA)

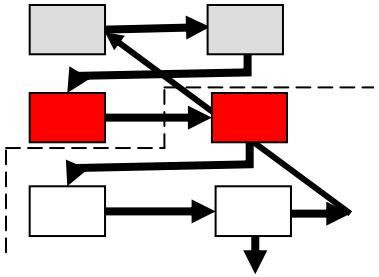


- **Purpose**: Investigate the different ways control tasks can be performed in JFC. These will provide design constraints for future systems (i.e., indicate which strategies may need to be supported somehow).
- **Method**: SMEs presented with activities identified in each work function from the ConTA and probed on how they might be accomplished. Developed a flow chart of the strategy.

Example: Determining required capabilities (Capabilities Analysis Work Function)



Identification of Design Requirements and Design Concepts



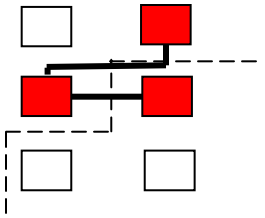
- Top-down analyses used to identify **design requirements** (opportunities or needs for design interventions) and propose **design concepts** in the following categories:
  - Technological Aid
  - Process/ Policy
  - Organization

Design Requirement: What is needed? (solution-independent)

Design Concept: A potential solution

- The StratA helped identify design constraints

Identification of Design Requirements and Design Concepts - WDA



- **Method**: Identify information requirements based on assessing each cell in ADS model

"How can we measure that?"

Abstraction Decomposition Space

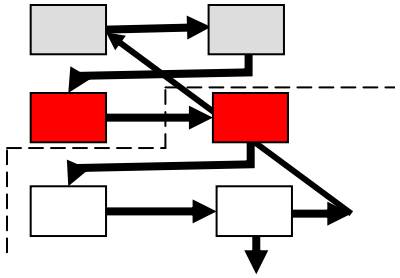
Functional Purposes	
Abstract Functions	
Purpose-Related Functions	
Object-Related Processes	
Physical Objects	

Information Requirements (Variables)

Design Requirements for each JFC function

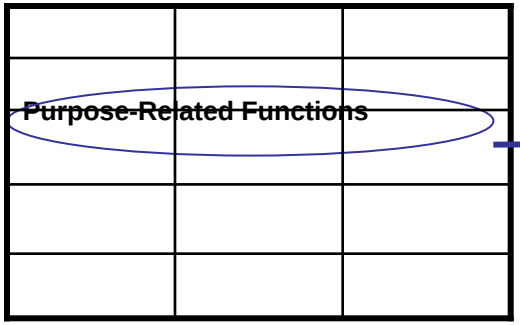
Abstract Function (ADS)	Information Requirements	Design Requirement	Design Seed
Minimize kill chain timeline	Kill chain timeline Time call for fire is made Time response to call is initiated Time response to call for fire ends	Need awareness of timeline between call for fire and response	**Technology**: list of calls for fire and the time that has passed since they were received; coding could be used to indicate calls waiting for response longer than a particular time; could include urgency and priority ratings **Process**: keep track of

Identification of Design Requirements and Design Concepts - ConTA



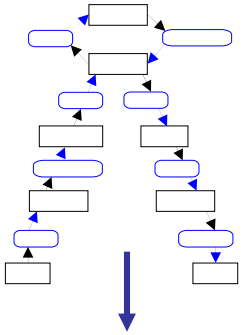
- **Method**: identify decisions to be made during each DL, followed by information requirements

Work Domain Analysis: ADS



Work Functions

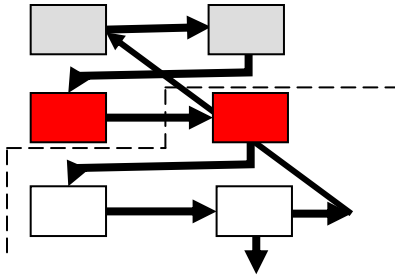
Control Task Analysis: Work Functions and Decision Ladders (DLs)



Decisions with Design Potential

Decision	Information Requirements	Design Requirement	Design Concept
Does the current target list need to be changed?	Target list Time/date target list was updated Arrival of new information (e.g., commander's guidance,	Need awareness that target list requires changing	**Technology**: alert or coding indicating time/date target list was last updated **Organization**: personnel/ system devoted to reviewing target lists **Process**: regular review of target

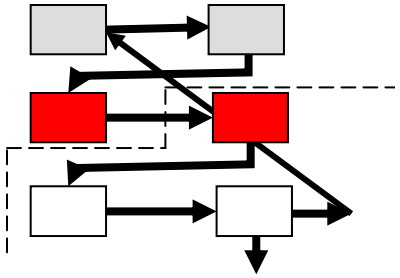
Identification of Design Constraints – StratA



- **Method**: Strategies identified in the analyses were examined and ways in which these strategies would constrain designs were specified

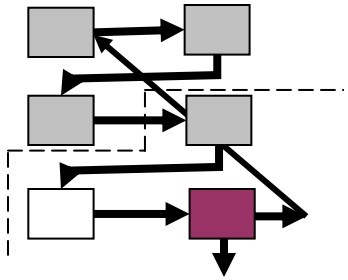
Decision	Strategies to be Supported	Design Constraints
How can I represent space and spatial relations?	Paper maps	Systems and/or processes must accommodate the fact that different people prefer different information presentation methods. Incorporate a means for easily translating information from a paper map to an electronic map, and possibly vice versa.
	Computer displays	

Identification of Design Requirements and Design Concepts – Design Themes



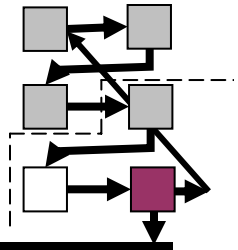
- Eight overarching design themes emerged in the design landscape for the future JFCC, producing several hundred design requirements and design concepts.
- Design themes were:
  - Decision, planning and coordination support
  - Availability of baseline and real-time information
  - Data/information fusion
  - Information presentation
  - Streamlined communications
  - Training
  - Measurement of effectiveness and performance
  - Team structure

Developing Options for Experimentation



- Design concepts related to some of the primary design requirements identified were aggregated and considered for experimentation potential
- Experimental conditions, metrics, measures, evaluation criteria and design hypotheses were developed for the aggregated design concepts
- Experimentation ideas were categorized based on the expected implementation schedule:
  - Short-term (within 12-18 months)
  - Medium-term (approx. 2-5 years)
  - Long-term (longer than 5 years)

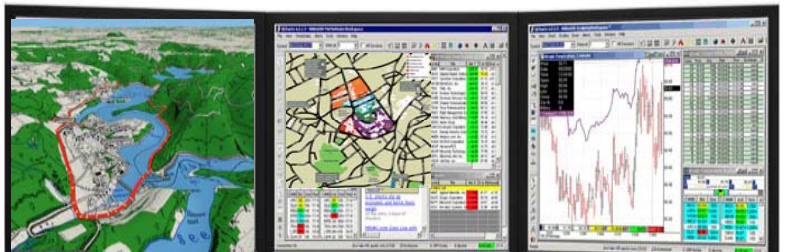
Developing Options for Experimentation: An Example



Design Requirement	Short-Term	Medium-Term	Long-Term
Need to update plans when changes are required	General Design Concept: Alert indicating that plans need to be changed (e.g., plans for targeting, engagement priority, etc.) (Technology) Experimental Conditions: Alert present or absent; Varying amounts of information present with alert (e.g., explanation as to why changes are required is present or absent) Metrics: Response time to choose to change plans; Appropriateness of plan changes implemented; Design Hypotheses: Operators change plans faster when alerts are present compared to when they are absent; Operators change plans more appropriately when an explanation regarding the	General Design Concept: Specialized teams with different responsibilities, such as monitoring different resources or locations, developing MOEs and MOPs versus evaluating plans using the MOEs and MOPs (Organization) Experimental Conditions: Divide team responsibilities associated with planning and updating plans in a variety of ways (e.g., functional vs. divisional team structure) Metrics: Team and team member responsibilities; Time required to develop and change plans; Appropriateness of plans given circumstances Design Hypotheses: Operators will develop and evaluate plans faster and more appropriately when teams have specialized responsibilities (e.g., work together regarding same locations and resources but with	General Design Concept: System that tracks real-time changes in weather, terrain, battlefield dynamics , resources, etc and indicates how they pertain to plans (Technology/ Process) Experimental Conditions: Varying degrees of human control over the tracking of information changes (all manual, semi-automatic, all automatic); Manipulations associated with algorithms designed to match information changes with plans (degree of change required to initiate an indicator/ alert that plans may be affected) Metrics/ Measures/ Evaluation Criteria: Baseline information; Changes to information; Sensitivity of system to change (e.g., how much information change is required to lead to an indicator/ alert that plans may be affected) Design Hypotheses: Operators change plans faster and more appropriately when changes are tracked automatically and when the system is highly sensitive providing

Concluding Remarks

- The approach was very effective for identifying several hundred design requirements for the ‘to-be’ JFC work domain
  - incorporated into a specification of a potential future JFC operational capability for the Canadian Forces
- Traceability of results from knowledge acquisition through work analysis to design
- Results applicable to DRDC’s Technology Demonstrator Project on JFS
  - Experimentation options
  - Design concepts mapped to a JFS interface
  - Gap analysis of JFC tools



Any questions?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