

STATUS QUO



Commanders find it difficult to

- Construct more than a small portfolio of hand crafted plans
- Foresee impending plan breakage
- Generate branches and sequels during operations before plan breakage

NEW INSIGHTS

Interleaving planning and execution will result in faster decisions.

Multi-modal (sketch and speech) input will allow **commanders** to generate more and better options quickly.

Monitoring the status of an ongoing operation will direct where the **commander** should focus planning effort.

Deep Green ACHIEVEMENT

MAIN ACHIEVEMENT:

Allow the commander to think ahead, identify when a plan is going awry, and help develop alternatives "ahead of real time."

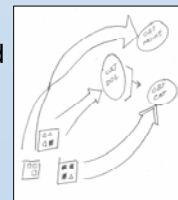


HOW IT WORKS:

Deep Green leaps the man-machine barrier with **Commander's Associate**, enabling rapid decision-action cycles with much less effort

Sketch to Plan: uses free-hand sketching and speech to induce commander-created options

Sketch to Decide: presents multi-dimensional information in a manner that enhances commander's battlefield visualization



Commanders avoid the Black Swan (unanticipated plan breakage) via **Crystal Ball** proactive analysis of relevant futures

Enhanced cognitive understanding of battlefield dynamics via high-speed **Blitzkrieg** combat model

ASSUMPTIONS AND LIMITATIONS:

- Deep Green is a tool that will be inserted into Battle Command Systems like CPoF or FBCB2 systems.
- Deep Green is limited to brigade and below
- Deep Green creates a new OODA loop paradigm

QUANTITATIVE IMPACT

Sketch to Plan: Accurate recognition of sketched MIL STD 2525b symbols

Sketch to Plan: Accurate machine induction of user's intended plan

Crystal Ball: Reduce blind alleys during execution. (prevent less than three good options available)

Blitzkrieg: Reduced time to evaluate combinations of representative Blue and Red courses of action

Overall System: Reduce staff requirements

Overall System: Enhance commanders' performance

END-OF-PHASE GOAL



Deep Green technology integrated into fielded battle command systems, such as CPoF and the PASS

Commander-driven Battle Command that Interleaves Anticipatory Planning and Adaptive Execution

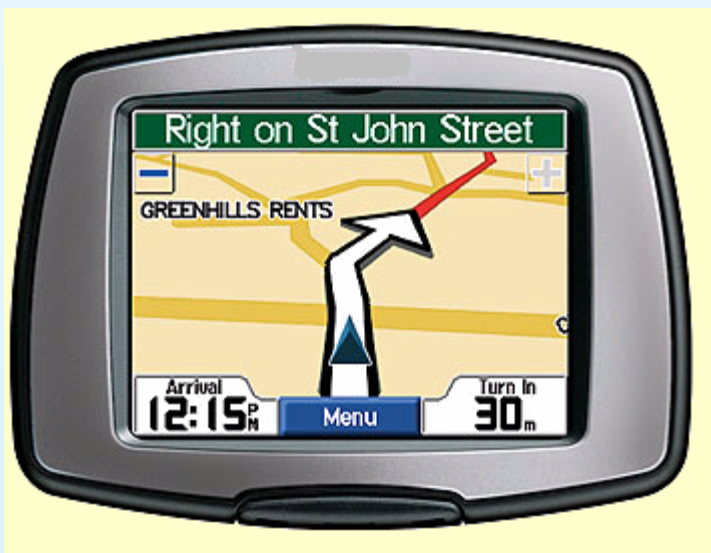


DEEP GREEN

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Information Processing Technology Office

14 APR 08

Harbingers of a New Paradigm



- In many role-playing *computer games*, if the player misses a key or item needed later in the adventure, the item is moved to put it back into the user's path.
- This involves crude predictive analysis to judge where the player is heading.

- Automotive GPS systems re-calculate a new route if the user takes a wrong turn.

- *Re-planning is done after the user makes a mistake.*
- *This works because the task is simple, there is no need to coordinate with others, there are few resource constraints, and re-planning takes little time.*
- *This is largely the paradigm used today in planning staffs during execution of operations..*

In Deep Green the re-planning would be done in advance – proactively, not reactively.

- This would be like having six or seven alternatives planned *before* you make a mistake or *before* traffic gets heavy.
- This would be like having six or seven possible key locations and then presenting the key when the user gets close to *any one*.

Lean Forward Headquarters

- If we assume large, secure pipes, we can move much of the analysis capability on our command posts to the “rear”



Mission Control, Johnson Space Center

You see space for about 15 decision makers, but for each work station you see behind this wall are 2 to 5 other people and workstations doing the analysis to feed information to the decision makers!

Staffs and bureaucracies are like goldfish; they grow to consume all available resources.



The Need



- Information superiority is no a “given”
- How does one achieve decision superiority when information superiority is not a given?
- Commander’s role:
 - Understand – Visualize – Describe – Direct –
- Visualization happens in the human’s head, not on a screen
- Ender’s Game
 - **Wrong**: battle command and training systems integrated
 - **Correct**: battle command and training systems that are the same
- What we need are tools to help...
 - Average commanders be good and
 - Good commanders be great

- Tools to help commanders generate options quickly
 - Infer commander's intent (*visualize* → *describe*)
 - Understand the goals, concept of operations, etc.
- Understand the unfolding operation and anticipate “black swans” (*understand* → *visualize*)
- Present information in a way that aids in cognition (*understand*)
 - Not just colors, lines, and blinky lights
 - If tools understand “intent,” they can collect and present the **right information** in the **right way** at the **right time** to aid in understanding and visualization
- Large staffs in bloated TOC's do some of this today
 - Tools are needed to help a lean staff do this more effectively?



... And These Tools Must Learn



- Tools must learn and *help the commanders learn*
- ***Both commanders and tools should learn:***
 - *Commander's preferences and biases*
 - *Enemy tactics*
 - *Friendly TTPs*
 - *What has worked and not worked in previous operations*
 - *Not after action review – during action reviews*
 - *There are no observer/controllers during a battle*
 - *73 Easting took a year; Masr El Sharif took a year; could we do this in minutes?*

“Crystal Ball” updates assessments with information from ongoing operations

Subordinates execute decisions

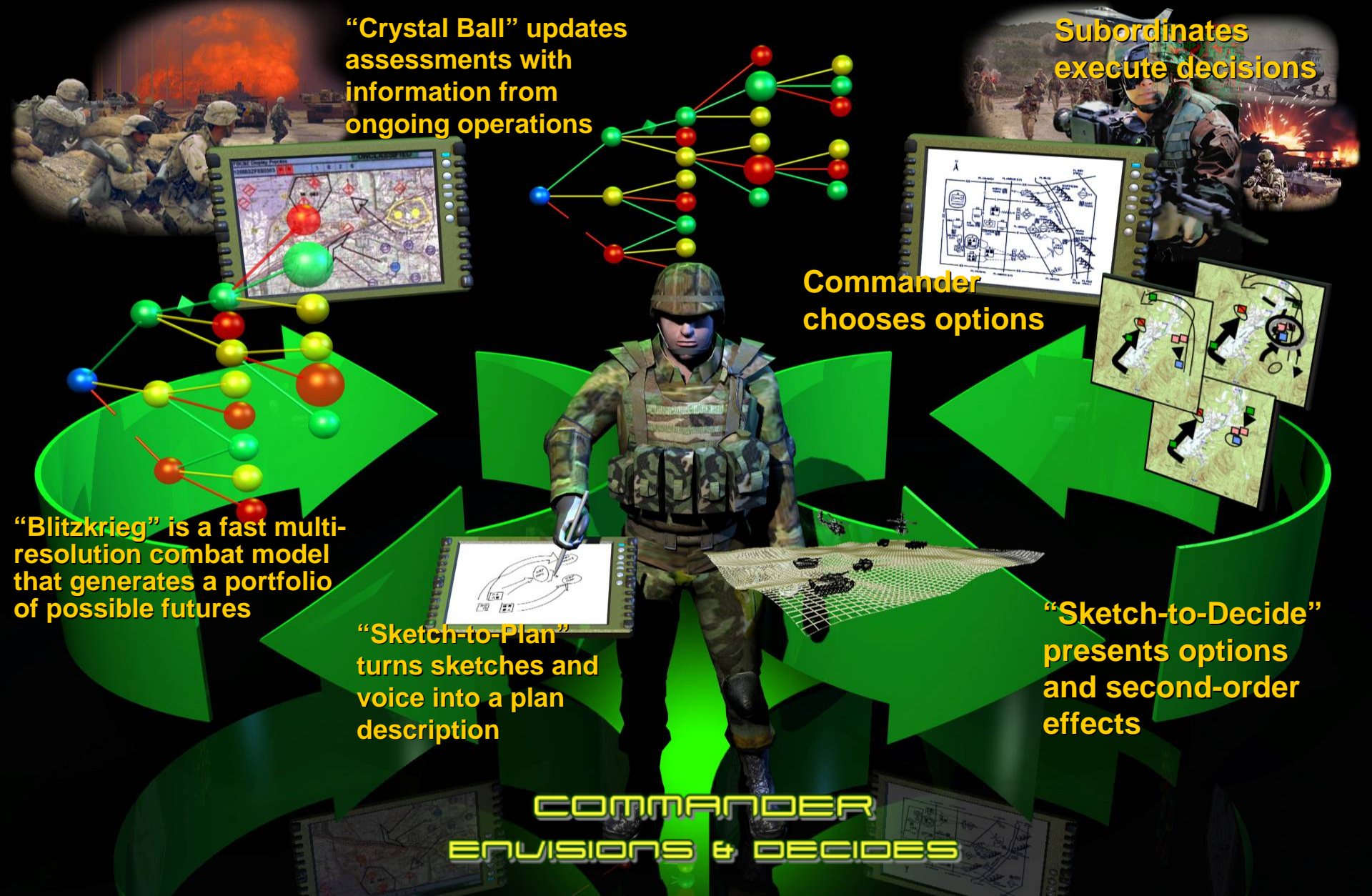
Commander chooses options

“Blitzkrieg” is a fast multi-resolution combat model that generates a portfolio of possible futures

“Sketch-to-Plan” turns sketches and voice into a plan description

“Sketch-to-Decide” presents options and second-order effects

COMMANDER
ENVISIONS & DECIDES





The Deep Green Vision



- Enhances commanders' option generation and decision processes
 - *Plan understanding* from multi-modal human sketching and speech
 - Intuitive presentation of decision points and second- and third-order effects of decisions
- Avoids bad “black swans” (unanticipated plan breakage) by predicting likely futures and building options before they are needed
- Generates a broad spectrum of possible futures with an instant-response, multi-resolution combat modeler
- Streamlined transition to the battle command community

“All current battle command efforts provide incremental improvements over existing capabilities. The only thing that provides something I don't have today is Deep Green.”

BG Justice, Deputy Program Executive Officer for Command, Control and Communications Tactical (PEO C3T)



Gaps and Barriers

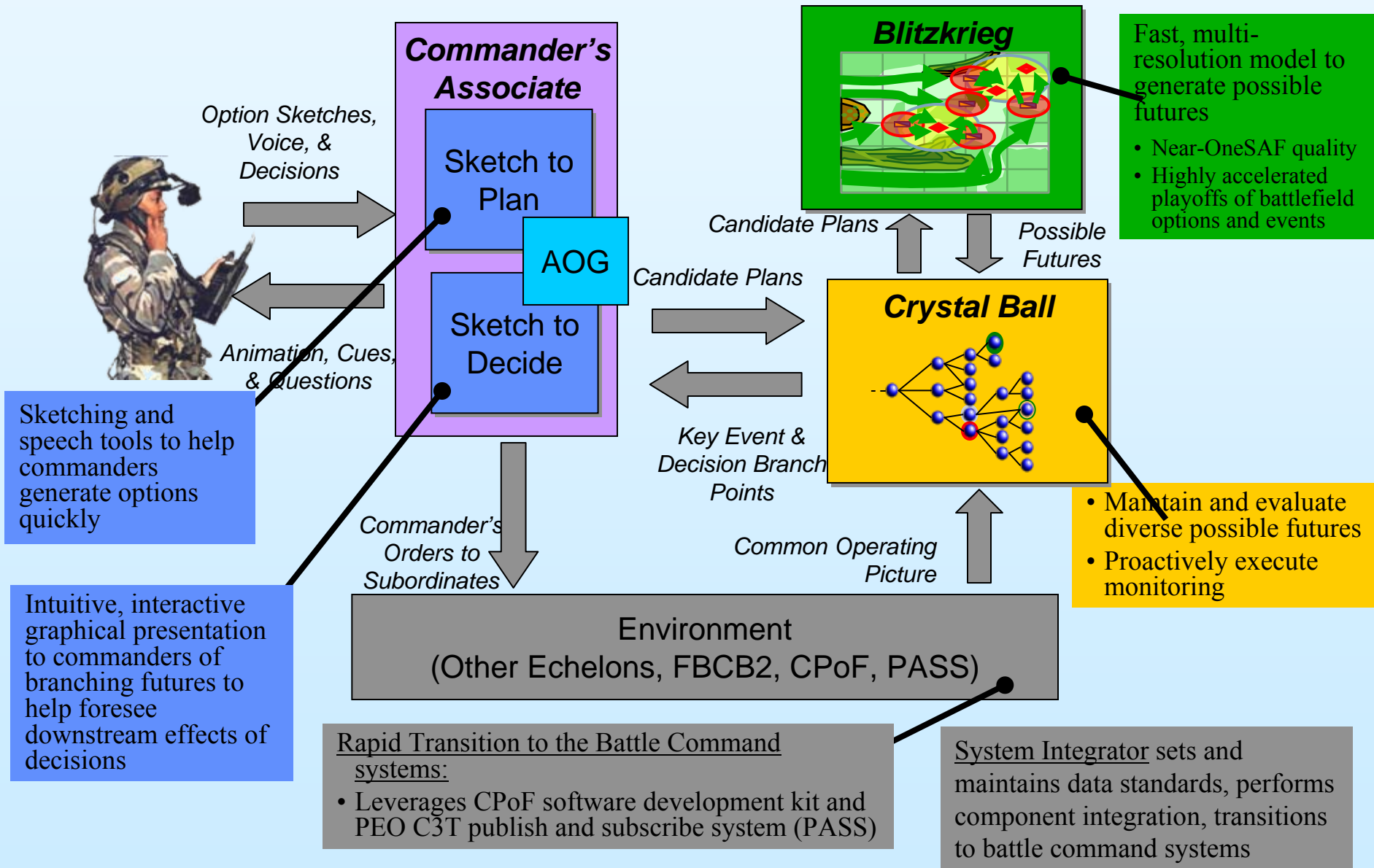


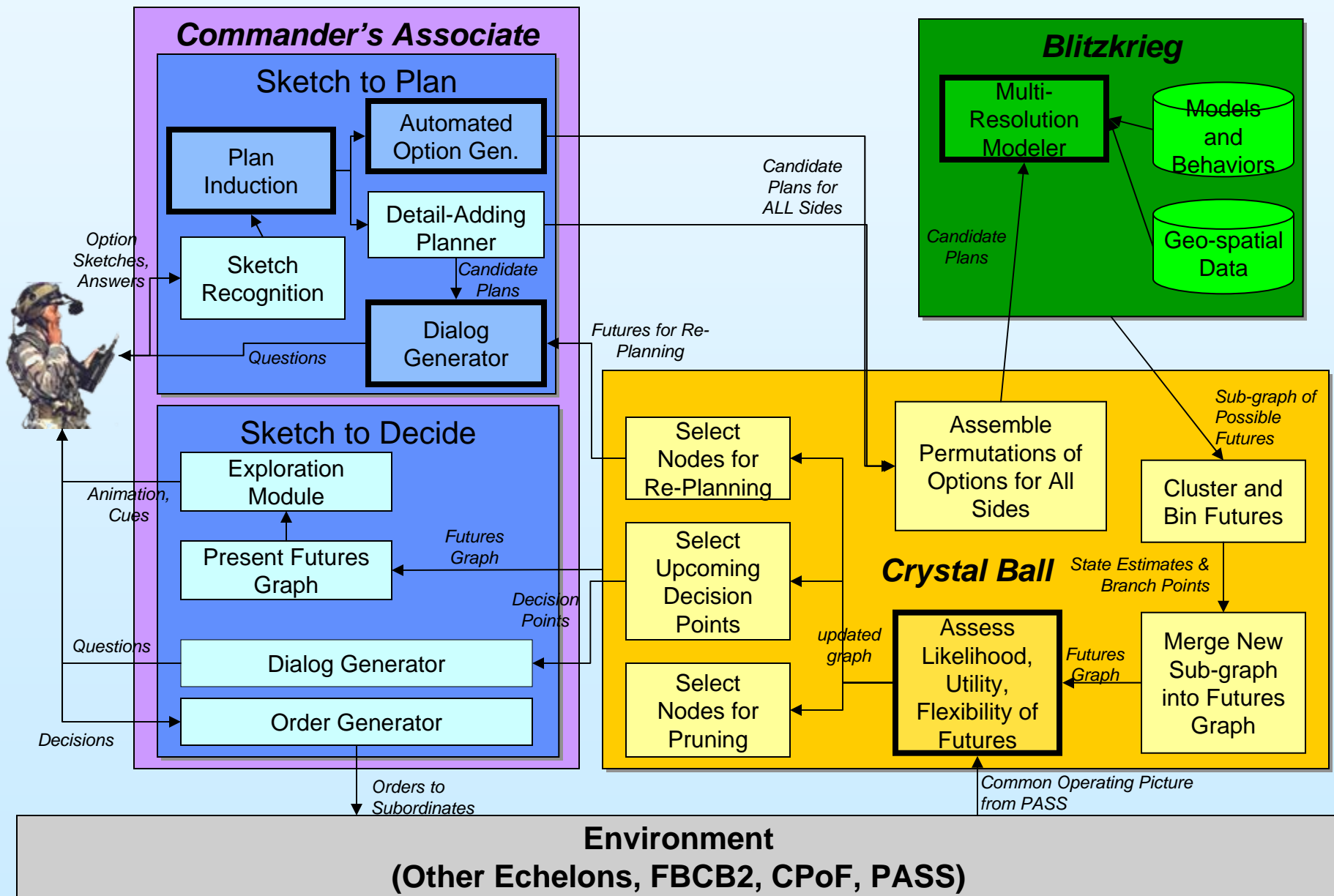
- Army written requirements for machine support for *commander-driven* planning and execution (italics are DARPA's):
 - Commanders require capabilities to enable more *rapid decision – action cycles, with much less effort* (TRADOC)
 - Capabilities to automatically present commanders with *relevant potential courses of action* (ARMY PEO C3T)
 - Enhanced cognitive *understanding of battlefield dynamics* (ARMY PEO C3T)
- Commanders find it difficult to:
 - Construct more than a small portfolio of hand-crafted plans
 - Foresee impending plan breakage
 - Generate branches and sequels during operations *before* plan breakage

- New technology is needed for machine induction of intuitively expressed plans
- Existing AI planning & monitoring systems focus on full automation and can be brittle
- Current generation of combat models are too slow and require significant manual intervention

Today, commanders generate three courses of action, and then choose *one* to execute. Limited contingency planning is conducted; when the *one* plan breaks, the commander becomes reactive.

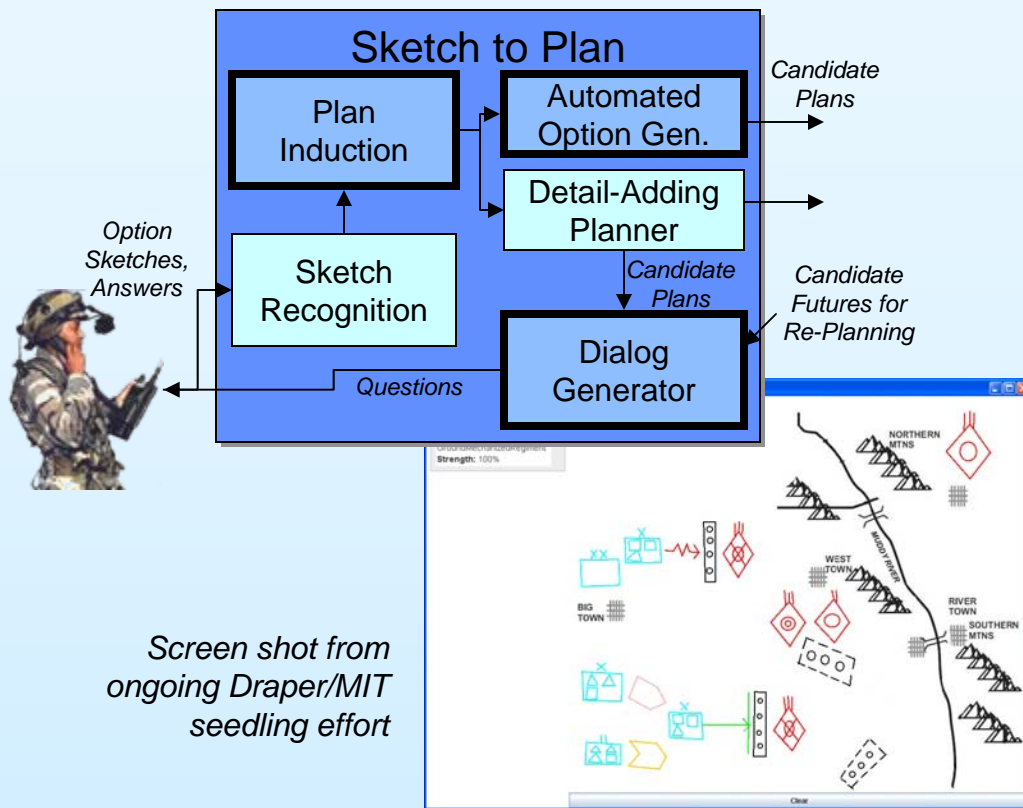
Deep Green is Commander-Driven





“Sketch to Plan” Concept

- Commander **draws** in “free hand” and **speaks**; STP interprets the symbols, replacing them with the correct standard military symbols
- STP *accurately* induces plans from sketch and speech, fills in missing details
- STP asks clarifying questions if it doesn’t understand the sketch
- This allows commanders to specify an option at a coarse level, then move on to the next cognitive task



Screen shot from ongoing Draper/MIT seedling effort

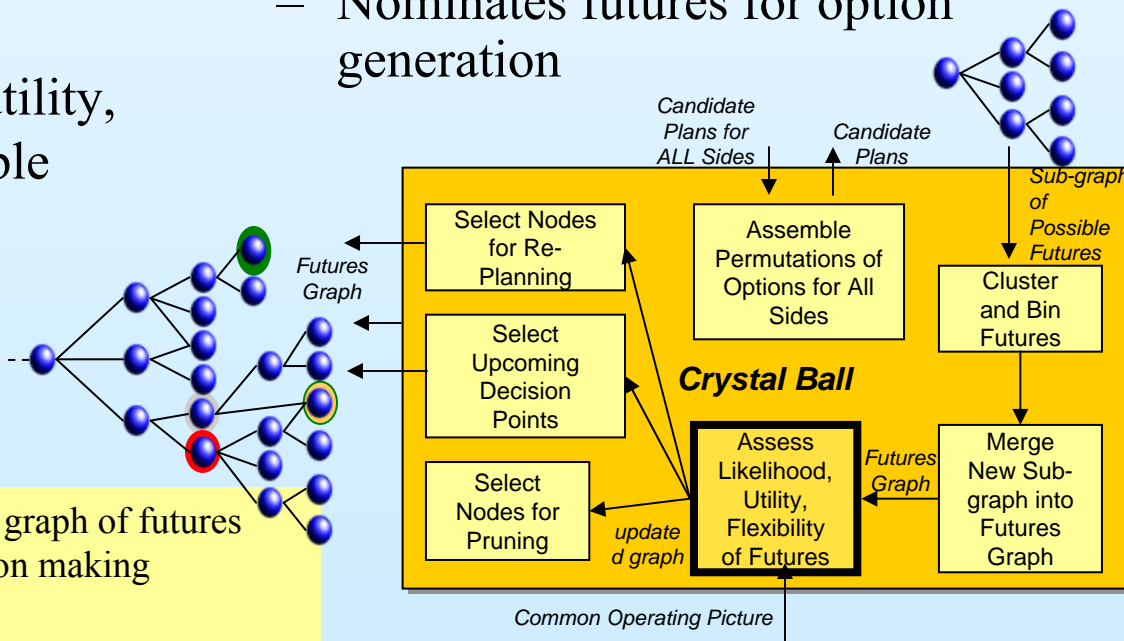
DARPA Hard: Inferring plan from sketch understanding, including clarifying questions between the commander and **Sketch to Plan**; automated option generation

Why We Think We Can Get There:

- Current work in military sketching (Forbus, Cohen)
- Seedling effort with Draper Labs and MIT CSAIL (Davis)
- Current work on mixed-initiative planning (Allen, best AAAI paper 2007)
- Prior work on “natural” commander’s intent language (Alphatech/BAE)
- Recent work in semi-automated plan generation (Myers, Wilkins), playbook approaches to semi-autonomous control (Goldman)

- During Option Generation
 - Clusters outputs of Blitzkrieg
 - Merges outputs from Blitzkrieg into graph of possible futures
 - Computes likelihood, utility, and flexibility of possible futures

- During Execution Monitoring
 - Monitors execution of operation
 - Updates estimates of likelihood, utility, and flexibility
 - Nominates futures for option generation

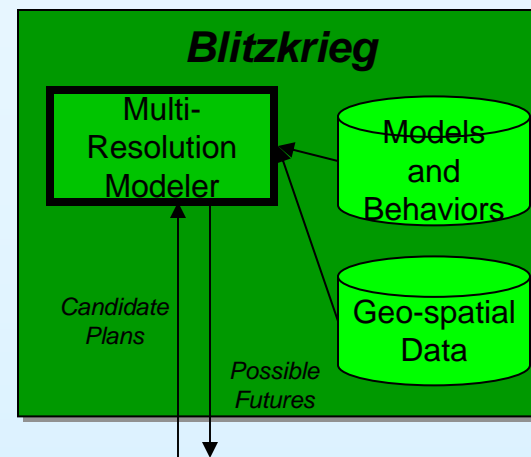


DARPA Hard: Maintaining an evolving graph of futures while identifying key branches for decision making

Why We Think We Can Get There:

- Seedling effort with ISI (Cohen)
- Recent developments in machine learning: Incremental case-based reasoning (Cox), Hybrid Bayesian networks (Pattipati), Structured Bayesian networks (Koller)

- High speed combat model links the portfolio of plans to potential battlefield outcomes
- Uses multi-resolution modeling (components of varying resolution) to achieve acceleration
- No human intervention during execution
- Uses hybrid of quantitative and qualitative methods to identify branch points
- Permits large time warping

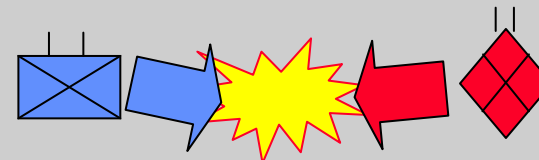


DARPA Hard:

- Determining qualitative branch points and using quantitative techniques to assess likelihoods of each branch
- Determining when and how to dynamically adjust model resolution to answer the appropriate question
- Massive time warping with little loss of fidelity

Why We Think We Can Get There:

- Multi-trajectory simulation research (Gilmer, Sullivan)
- Hybrid of quantitative modeling and qualitative physics (Forbus)



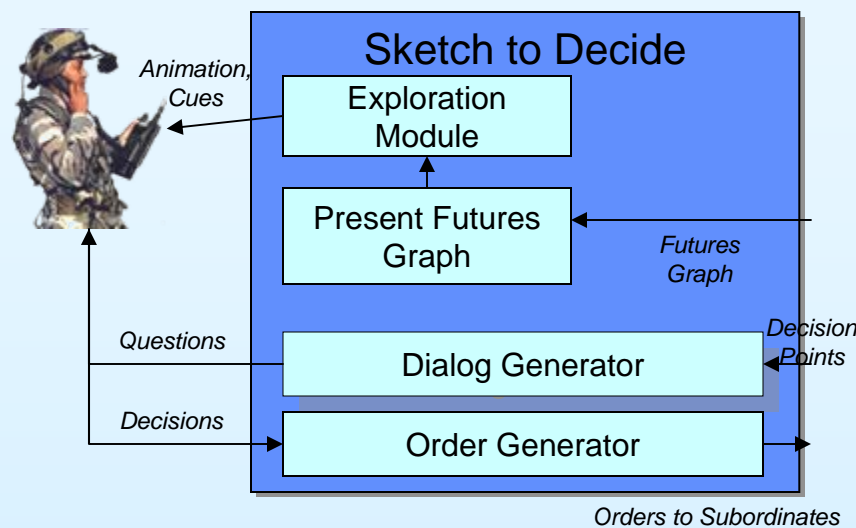
Example: two forces collide.

Qualitatively different outcomes include:

- Blue is destroyed
- Red is destroyed
- Blue begins to lose and withdraws
- Red begins to lose and withdraws
- The two forces choose not to engage
- And so on...

“Sketch to Decide” Concept

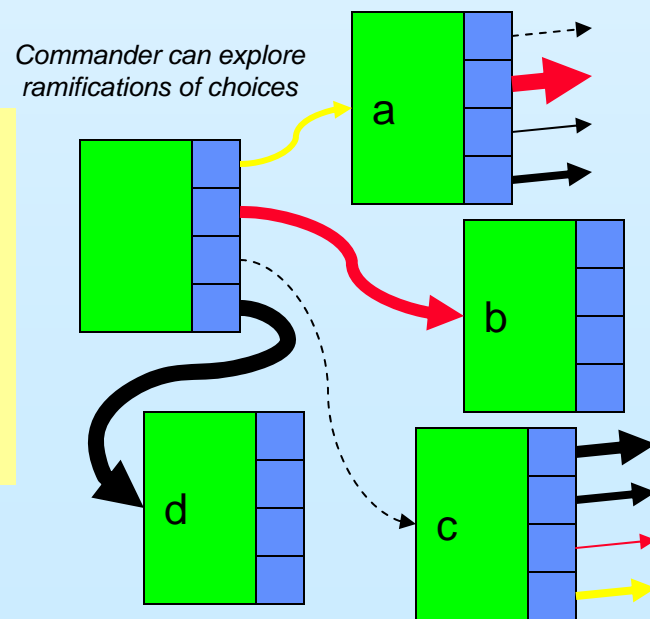
- **Sketch to Decide** provides a window into the futures that have been generated by **Blitzkrieg**.
- Allows the commander to see how options may play out by following different “flows”
- Intuitive ways to depict likelihood, goodness, and flexibility as flows are explored



Hard: Presentation of branching possible futures to the commander in an intuitive way; Supporting user understanding of branch points across multiple decision dimensions and utilities

Why We Think We Can Get There:

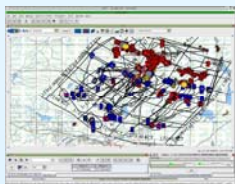
- Recent efforts to generate “comic graphs” to show passage of time (Forbus)
- Recent work (Han) shows temporal relationships
- Seedling effort with Draper Labs and MIT CSAIL (Davis)



Phase I

“Functional Components”

12 months



SAF Plan
View Display



Deep Green

- Component tests
- Mid Intensity Conflict (e.g., 3rd ID during invasion of Iraq, Masr al Sharif)
- Test SMEs: Component testers
- SMEs interact directly with various components
- OneSAF used as exercise driver

Phase II

“Functional, Integrated System”

12 months



Battle
Command

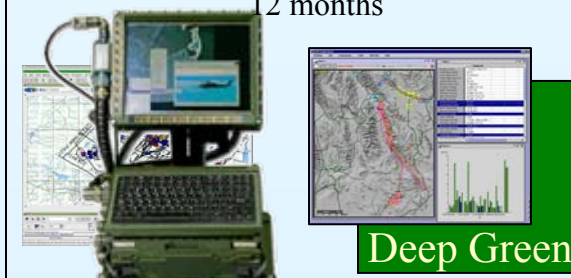
Deep Green

- A series of force-on-force, human-in-the-loop experiments in a simulation center
- Counter-insurgency operations
- Test SMEs: Commander, S-3 (operations officer), and S-2 (intelligence officer)
- Staff interacts directly with the Commander’s Associate
- OneSAF used as exercise driver

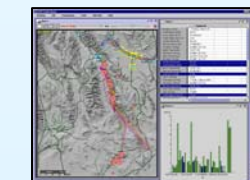
Phase III

“Integrated with Battle Command”

12 months



Battle
Command



Deep Green

CPOF with Deep Green
“Under the Hood”

- A series of force-on-force, human-in-the-loop experiments in a simulation center and a tactical environment
- Large, Three-Block War Operation (e.g., Falluja or Basra)
- Test SMEs: Commander, S-3 (operations officer), fire support officer, engineer officer, and S-2 (intelligence officer)
- Staff interacts with Commander’s Associate through CPOF
- OneSAF used as exercise driver



Go/No Go Criteria



Task	Phase I	Phase II	Phase III
<p>Sketch to Plan: Accurate recognition of sketched MIL STD 2525b symbols. $F = (2 \times H \times P) / (H + P) \times 100$, where #T = number of symbols that should be correctly interpreted #I = number of symbols that are interpreted H = Hit rate = number of correctly interpreted symbols / #T P = Precision = 1 - False positive rate = number of correctly interpreted symbols / #I</p>	<p>A subset of the MIL STD 2525b symbols (approx. 1/5th of the total) are commonly used when describing military operations. For this subset, $F > 90\%$</p>	<p>For a subset consisting of 80% of all MIL STD 2525b symbols, $F > 90\%$</p>	<p>For all MIL STD 2525b symbols, $F > 90\%$</p>
<p>Sketch to Plan: Accurate machine induction of user's intended plan. Subject matter experts judge key aspects of machine-induced plans by playing them through OneSAF. $S = (\# \text{ aspects of plan judged to be correct} / \# \text{ aspects of plan entered by user}) \times 100$</p>	<p>$S > 70\%$</p>	<p>$S > 80\%$</p>	<p>$S > 90\%$</p>
<p>Crystal Ball: Reduce blind alleys during execution. A "blind alley" occurs during execution when Blue reaches an unpredicted or ill-prepared state (less than three good options available). $A = (\# \text{ blind alleys with Crystal Ball} / \# \text{ blind alleys without Crystal Ball}) \times 100$</p>	<p>$A < 80\%$</p>	<p>$A < 50\%$</p>	<p>$A < 20\%$</p>
<p>Blitzkrieg: Reduced time to evaluate combinations of representative Blue and Red courses of action. (Canonical test case will involve 3 Blue COAs vs. 3 Red COAs.)</p>	<p>Today: 120 min Deep Green < 30 min.</p>	<p>Today: 120 min. Deep Green < 10 min.</p>	<p>Today: 120 min. Deep Green < 3 min.</p>
<p>Overall System: Reduce staff requirements. Measured by reduction in staff usually needed to accomplish brigade planning/execution for the milestone scenario. $T = \# \text{ Staff With Deep Green} / \# \text{ Staff Without Deep Green}$</p>	<p>$T < 80\%$</p>	<p>$T < 50\%$</p>	<p>$T < 25\%$</p>
<p>Overall System: Commander's Performance. Measured by a single numerical score P, computed as a weighted function $f(\bullet)$ of mission accomplishment, friendly losses, enemy losses, neutral losses, time to accomplish tasks, and various human factors. $P = f(\text{with Deep Green}) / f(\text{without Deep Green})$</p>	<p>$P \geq 1$</p>	<p>$P > 1$</p>	<p>$P > 2$</p>