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## **Draft Working paper**

### **MANAGING INCREMENTAL COMMITMENT: AN ANALYTIC CHALLENGE**

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#### **ABSTRACT**

Decision making often consists of incremental moves toward some selected objective, which can be reconsidered as knowledge emerges—as when an individual chooses a career, or a commander picks a military course of action. Analyzing these decision strategy options as if they were single integral commitments can distort comparison. However, rigorous normative treatment of complex act-event sequences is often impractical.

Alternative analytic aids to managing incremental commitment usefully are explored, e.g.

- Evaluation of integral options adjusted for flexibility
- Successive decision analyses of incremental options
- Simplified information gathering decision trees
- Feedback to decider on evolving operation success
- Rehearsing deciders on potential recognition-primed sequences

## **1 PROBLEM**

### ***1.1 What is incremental commitment?***

Although it is usually more convenient to think about, and certainly to analyze, decision-making as if it consisted of single clear-cut choice, the real decision process is often significantly different. You test the water with your toe, then leg, before taking the plunge. Typically, there is no single point in time where the decision is made; but there is a succession of small, only partly reversible steps. No one step may deserve--or have the time available for--much deliberate effort, but the end-product may represent a major commitment of resources, say to attack an

enemy or market a new product. This is a perplexing decision situation where analytic aid would be most welcome

### *1.1.1 Examples.*

In everyday life, such decision-making is typified by a career choice that, piece-by-piece falls into (or out of) place, as a result of a succession of school, summer job, interview, etc. moves. Each move responds to new events and information. There may not even be any point in time at which the "decision" can be said to be definitively made. Careers may continuously evolve.

Lack of an unambiguous decision point may lead to drift (as in many career evolutions) or leave the way open for regretted escalation (Staw and Ross, 19xx), as in the Vietnam involvement. At the national policy level, in the 80s Congress demanded to know when the Administration approved the infamous Iranian arms-for-hostages "decision". President Reagan claimed there was never any definite decision point. "It just ended up being a trade of arms for hostages".

In military combat, a single "course of action," say, "attack to the North" may be proposed, but the commander can back off or redirect his forces if the unfolding situation warrants (see Appendix A).

In business, a "decision" to launch a new product will typically be characterized by a complex incremental commitment of attention and resources which eventually reaches some critical institutional momentum from which there is no turning back. Along the way, there may be back-tracking, diversion to a somewhat different product or, of course, aborting the whole project.

## **1.2 Methodology needed**

### *1.2.1 Operational tools*

*Form of ultimate prescription.* The methodology may take the form of operational aids which can be used during actual decision making, conceivably in "real time," i.e., used immediately before the incremental decisions are made. Especially in the latter case, such aids would need to be extremely economical of evaluation effort i.e., require little effort and delay at each application. Such aids might be in the form of computerized decision rules, graphic displays or manual procedures.

### *1.2.2 Training*

Alternatively, and perhaps more realistically, the aids may serve to train deciders to manage incremental commitment situations, either as part of school training, or in the planning phase of an particular operation (e.g. military campaign).

## 2 HOW EXPERTS NOW MAKE INCREMENTAL COMMITMENTS

### 2.1.1 *Descriptive theory.*

Existing research findings on the nature of incremental decision making can be adapted to the special case of incremental commitment. A key hypothesis is that the proficient decider tends to be recognition-primed (rather than analytic), at least in dynamic situations with little time to deliberate on successive actions (Klein, 1989). A second is that task conditions induce cognitive activity (Hammond, 1988) and that this may evolve as conditions change (Cohen, 1989 [*Marvin Cohen's chapter in a current book, Klein also has a chapter in*]). A third is that the controlling element is affective rather than cognitive, i.e., incremental response is mediated by a feeling of enthusiasm or excitement (Hogarth, 1981). [REPET?]

### 2.2 *Emulating experts deciders*

#### 2.2.1 *How experts make incremental decisions.*

Incremental decision making as a class of human behavior, broader than incremental commitment, has been a topic of descriptive psychological research at least since Edwards (1962) characterized it as a series of interdependent choices carried out in a changing environment.

Important aspects of the task, or special cases, have been addressed in the psychological literature, for example:

? confirmation bias in evolving inference leading up to a decision deadline (Tolcott & ?)

? recurring comparable choices, typified by chess (de Groot, 1965) and fire fighting effort (Klein, 1986); and

? control systems, where a fixed set of control variables are continuously or periodically reset with a view to achieving some measurable objective (Brehmer and Allard, undated).

However, other than Hogarth's (1981) and Connolly's (1986, 1988) thought-provoking but broad reflections on the importance and nature of the problem, we are not aware of any research specifically addressing that special case of incremental decision-making, with which we are concerned, i.e., incremental and hierarchical commitment. Certainly we have found nothing that might provide the basis for a decision aiding technology applied to such a case.

Nevertheless, recent theoretical work on cognition in incremental situations is highly relevant. Hammond (1988) presents a taxonomy of incremental judgmental tasks and the cognitive

activities that he posits they induce. Specifically, tasks are characterized in terms of time period, number, redundancy and measurement of cues, surface features such as display of cues, etc. Cognitive activities are characterized in terms of cognitive control, rate of data processing, errors, conscious awareness, confidence and organizing principle and related to a higher order cognitive continuum, from intuitive, through quasi-rational to analytic. He theorizes how the one taxonomy induces the other and tentatively suggests that the connection may be prescriptive as well as descriptive.

Cohen (198x?) [*assumption based reasoning paper*] has identified more specific cognitive responses to developments in a incremental situation, such as conflict resolution heuristics, the evolution of assumption-based reasoning, and the meta-cognitive process whereby cognition strategy itself adapts to changing circumstances.

Connolly and Wagner (1988) propose a "decision cycle" mechanism whereby feedback involving goal directed action, actual consequences and current goal-state assessment guide the evolution of incremental decisions.

Klein (1989) presents empirical evidence (based on 150 retrospective field interviews) that proficient deciders under time pressure use a strategy of recognizing familiar situations and check out, serially, action responses that are typical of them. The response may be mediated by a directly felt degree of enthusiasm, without overt cognitive component (Hogarth, 1981). These findings provide a central focus for this proposal.

Klein observes that typically only novices use analytic concurrent evaluation, long advocated by decision analysts. Like Hammond, he does, however, suggest that certain decision tasks, say characterized by long lead time or the need for conflict resolution, induce more analytic activity.

### 2.2.2 *Prescriptive implications of expert decider practice.*

In general, this dominantly descriptive research does not have unambiguous *prescriptive* implications. We may agree that the most proficient flyers (birds) flap their wings, but that man's best shot at flying (planes or rockets) may be based on quite different principles. Closer to home, chess grandmasters' strategies may be based on pattern recognition, but they may eventually be beaten by computers relying on number-crunching concurrent evaluation.

The current controversy between AI/expert system advocates and more traditional decision analysts revolves on just this issue: whether it is better to attempt to emulate or to enhance procedures used by experts (Henrion and Cooley, 1987).

Several authors have addressed the unmet need to aid the management of incremental commitment, as a special case of incremental decision making (Connolly, 1988; Hogarth, 1981;

Klein, 1989; Brown, 1989). However, we are aware of no published research which makes a significant prescriptive contribution to solving the problem.

### 2.2.3 [DRO? Research paradigms

A recent development in methodology for addressing such issues has been the emergence of the "naturalistic" school of empirical research (Klein, 1987). It takes the position (which we share) that complex human decision behavior can often best be studied (and evaluated for proficiency) in its natural "real" setting.

This contrasts with the, until recently dominant, "laboratory" school, where homogeneous groups of convenient subjects are given carefully contrived tasks according to the classical experimental paradigm. (Kahneman et al., 1982). Klein (1989) points out that such research may be premature before the key variables have been established (e.g., novice vs. expert).

We would characterize the difference between the two schools—laboratory vs naturalistic--as: definitive answers to a contrived problem (e.g., how psychology majors respond to paper tasks, with hypothetical objectives, for money) vs. tentative answers to a more interesting problem--how people behave in the real world, and with what success.

Techniques for measuring that success in naturalistic settings, whether for an aided or unaided decider, has been largely limited to researchers' impressionistic evaluation or appeal to an acknowledged expert arbiter. The popular alternative of testing whether the subject followed decision making *procedures* of which the researcher approved, begs the critical question (Klein, 1989). Appendix C discusses some of the issues involved.

## 3 PRESCRIPTIVE TOOLS

Any decision commitment process can be aided in a number of ways--including analyzing it as if it were a different process. Bibliography below gives some 50 relevant references related to this problem, though only a few, as noted, address it at all directly.

### 3.1 *Standard Decision theory*

The prescriptive decision aiding literature in general has long been dominated by normative, typically mathematical modelers, originally in the operations research. The most generally applicable approach, at least logically, has been that of statistical decision theory (Raiffa and Schlaifer, 1962). Its central paradigm is the maximization of expected utility; i.e. for any given option, the average utility of possible outcomes, weighted by the probability of each outcome. It can be implemented in either the extensive form (action by action, as in a decision tree) or normal form (complete strategies).

In principle, any decision problem can be addressed, including the incremental commitment case. Conceptually there is no difference between the evaluation of a single decision and the evaluation of a dynamic progression of smaller decisions (i.e., incremental steps). However, the

implementation in the incremental commitment case is typically more burdensome and technically difficult than the situation, or the available time, can justify, without unsatisfactory simplifications.

The first step in a conventional decision analysis is typically to specify the "immediate" act options, i.e., the first fork on a decision tree. This is perhaps the knottiest technical problem facing applied decision analysis. If the decision maker's problem is to compare the attractiveness of clearly specified integral current options--for example, a congressman deciding how to cast his vote on a bill before him--we can nearly always productively improve on common sense by decision analysis. However, in the more common case of an intrinsically incremental decision process the problem of formulating what integral options to compare is often so troublesome that decision analysis is ineffectual (see discussion on pp. 359-363 in Brown, *et al.* 1974).

In theory, it is always possible to determine, in any decision situation, what is the first action commitment to be made, and to analyze that choice. The trouble is, that may not be the most interesting or most profitable choice to devote one's analytic resources to analyzing, if the decision problem is essentially one of incremental commitment. If the basic choice is whether to "go West", it may not be very helpful to spend much time on the immediate choice, which is whether to acquire a covered wagon.

In army combat, the strategy choice is normally between 3-4 "courses of action." (COA). Each is described in 2-3 sentences such as: "Take defensive posture. Secure perimeter. Prepare for airlift." [*replace w ref to 2.2.2*] It may also specify some more specific steps. There may be alternative ways of specifying the COAs. For example, instead of distinguishing offensive from defensive COAs, one might separate out different priorities, such as "airborne resupply" (which would work for both offensive and defensive strategies).

Normative research has been specifically applied to incremental decisions, for example with

- pre-decisional information gathering (Raiffa and Schlaifer, 1962),
- dynamic programming (Bellman and Dreyfus, 1962) and
- control theory (Brehmer and Allard, undated). In a few cases incremental commitment has been specifically addressed, with
- business investment (Rosenhead and Gupta, 19xx) and the
- valuation of flexibility (Merkhofer, 1977). [A-2]

Although such special purpose models may provide valuable logical insights, they do not readily lend themselves to operational decision aiding where little effort and elapsed time is available for any particular incremental commitment (as in e.g. battlefield situations where little more than half an hour may be available to decide on any particular initiative).

### 3.2 *Integral decision analysis of culminating commitments.*

One approach is to evaluate choice as if final commitment were to be made now, e.g., high-schooler pretends she is deciding now whether to be a dancer or architect, even though she will have plenty of chances to reconsider. In a combat decision on whether to attack an enemy depot the procedure would be to evaluate maximum assault on enemy depot (assuming all necessary preparatory commitments have been made, and no reasons have been found to turn back).

We thus evaluate potential culminating commitments as if they were integral (not incremental) choices. The decider would bear this evaluation in mind as he uses his normal, e.g., recognition-primed, intuitive processes on each incremental step. Since incremental commitment is typically a hierarchical process, there will be a choice of which level to make the comparison at (e.g., board stage coach vs. go West). An important consideration will be the elapsed time between steps at each level, and the stakes involved. (For guidance on when and how much analysis to do, see Brown and Ulvila, 197x. [*taxonomy*])

Integral substitution is relatively straightforward and may offer valuable insights into the real dynamic situation. However, it is crucial that the user understands that the problem solved is not exactly the problem he has and can appreciate the implications of the mismatch.

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If each incremental choice in a dynamic decision process is substantial enough, and especially if the choice may need to be justified, then it may be analyzed as an integral choice, in the conventional way. A major military procurement, for example, has well-defined decision points and systematic procedures for making the decisions. In this case, no new analytic structures are needed.

As Connolly (1986) has put it:

"Academic treatments of managerial decision making and problem solving commonly share the following three assumptions. First, the problem is taken to be well specified, either at

the outset or after some period of initial, pre-choice effort. Second, the goals or objectives are assumed to be clear, or to be brought to clarity during pre-decisional work. Finally, the focus of research interest is on the process by which the decision maker, using unaided reflection, consultative process, mathematical models, decision support systems, or whatever, selects an alternative from those available so as to maximally (or adequately) solve the problem initially formulated. The central image, then, is that of a single decisive act by which the decision maker hopes to move from a well-specified initial state (the unsolved problem) to a well-specified final state (the solved problem). The problem of felling a single tree highlights these characteristics, and we shall refer to analyses of this sort as "tree-felling" models."

Connolly goes on to argue that most important decisions, including many that are analyzed integrally are in fact incremental, "hedge-clipping" as he puts it. I agree.

### *3.2.1 Dangers*

In the author's wide experience of applying decision analysis in the conventional way, i.e., analyzing decisions as if they were integral, not incremental, I have frequently found that reality they was so incremental that my analysis (like that of other decision analysts) was only marginally useful.

In the process of observing and analyzing G3 performance on Army field exercises at Fort Carson and Fort Bragg, action responded even less than inference to surprising intelligence, i.e., the G3s were treating the decision process as unnecessarily integral [?] and not taking appropriate advantage of modifying incremental commitments.

\*\*\* Treating decision as integral undervalues strategies with more flexibility and those which benefit most from resolution of early uncertainty. [Expand?]

### *3.2.2 When integral substitution makes sense.*

Evaluating incremental decision processes as if they were a single integral choice may not always be inappropriate. It is relatively straightforward to do and may offer valuable insights into the incremental process it is substituting for. However, it is crucial that the analyst (or decider) appreciate the implications of any mismatch.

## **3.3 Modeling incremental steps explicitly**

One approach is to make the current immediate preparatory choice (e.g., putting a toe in the water) the focus of the analysis (possibly followed by analysis of the second step, when that becomes current, etc.). This often diverts attention from the essence of the incremental process (e.g., the aftermath of the plunge).

Analysis of the first step requires taking some position about what will happen at subsequent steps, and the whole process may rapidly become unmanageably burdensome or there simply

may not be enough time available. Simplifying variants have been developed, which do not require all subsequent acts to be evaluated (Brown, 1978) [*Elaborate*]. One of them used to analyze NATO mobilization decisions in the face of an uncertain Warsaw Pact attack is presented in Brown *et al.*, 1975. [*Nato Readiness Ddi Report*]

In the military combat case, the first step might be the complete COA as illustrated in Appendix A, or it might be more specific, e.g., to prepare a landing strip (through which to get reinforcements). Its evaluation might consider scenarios that might unfold over the time horizon of interest. For example, the probability of both environmental or enemy events (such as fog or excessive enemy bombardment) as well as own actions, either preparatory (securing perimeter) or culminating (continuing with original mission objective). As these events occur or not, a new "first step" evaluation would be called for. That evaluation might either be an updating of the same elements that went into the previous analysis; or, if unanticipated events occur, a brand new evaluation.

Clearly the latter case gives rise to the most burdensome evaluation. It may be prudent to assume that real war will be more unpredictable than the exercises we train in. Therefore, a succession of integral analyses may appear to work quite well in exercises but prove unmanageable in the real thing.

We can also look into different ways to formulate the course of action, e.g., it could specify a single goal such as "protect the north approach avenue," or it could specify several conflicting goals with some indication of priority between them (implicitly a multiattribute utility function). It could be partly overlapping or even nested, e.g., defense of Treysa and resisting a northern assault.

### 3.3.1 Acts as events

A major example of harmful simplifications in attempts to implement normative approaches is the common practice in decision analytic practice of modeling only part of the relevant information that becomes available between steps. Brown (1978) has argued that this common, but often inadvertent, practice in decision analysis circles invalidates much of the use of decision trees generally, and he has proposed alternative paradigms.

A recent research program, funded by ARI, on evolutionary decision making (Tolcott *et al.*, 1989) prescribes decision aids in naturalistic situations with evolving developments, but the focus is on a different case from incremental commitment: the case where information, and therefore inference, is changing, in preparation for a single decision deadline (i.e., not interleaved with incremental commitments). Specific attention is paid to the hypothesized "confirmation bias" and to measures for correcting for it.

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[Brown (1989) has proposed a basic logic involving normative models on which a computerized inference aid for updating evolving intelligence on the battlefield might be based.]

[Brown and Ulvila (1977) have developed a theoretical paradigm for matching decision-aiding options to decision situations, which is in principle adaptable to the special case of aids for the management of incremental commitment. Watson and Brown (1978) have developed a normative theory for determining how much analytic effort is justified to support any given decision.]

[Brown (1989) has proposed a general strategy of prescriptive research, i.e., aimed at enhancing decision practice, involving the fusion of descriptive and normative research, with case testing in naturalistic settings.]

[How should the decision evaluation task be formulated, so as to be an acceptably equivalent substitute for the real situation? What specific option(s) should be compared and in what sequence?]

### **3.4 *Aggregating options***

. A critical feature of the incremental commitment case is that the process can be addressed at different levels of aggregation, any one or more of which can be the focus of deliberate choice

#### *3.4.1 Where in the means-end chain focus choice?*

Take "Go West, young man!" The young man could focus his choice on any point or points in the following hierarchical means-ends chain, leading to a choice of culminating position:

- ? Go out the front door
- ? Buy covered wagon
- ? Head for Cheyenne
- ? Go West

Whether the choice is characterized as integral, and accordingly what the best way is to make it, depends on where, in such a chain, the focus of attention is.

#### *3.4.2 Relation to Organization Hierarchy*

The kind of continuum of action specification, from broad to specific, seems to correspond fairly closely to an organizational hierarchy. The President says: "keep Russia from overrunning Western Europe." The 8th Army says: "maintain control of the Fulda Gap." The Corp says: "protect the approach to Frankfurt." The Division says: "defend Treysa." The G-2 says: "find out what the Soviet 7th Tank Army is up to." The G-3 says: "prepare for an imminent attack either from the North or the South with equal emphasis." [*Adapt To New Scenario*]

However, all of these aren't actions, but basically concretizing the directions *as* given one level up. They are specified as goals, which is perhaps all that directions can be. Conditional decision

rules can be used to augment each level. For example, the President can add "and use tactical nuclear weapons if you absolutely have to." Just as the division commander can add "and move the reserves in this way if ...." The conditioning can be expressed several ways, at different levels of specificity. For example: "to the extent possible ...;" "if Mohawks can be spared by the Corps, use them to ...."

If these rules are computerized, the conditioning will surely have to be supplied by human judgment, e.g., "does it look as though the Russians are ...?" Multiple choice might be the way to elicit the conditioning.

### ***3.5 Evaluating Strategies***

Another approach is to analyze complete strategies by using, for example, normal form analysis described in Raiffa and Schlaifer (1962). In its extreme form, it amounts to analyzing an immense decision tree where all possibilities of action and information are laid out and analyzed all-in-one-go by what in decision theory is called "normal form analysis." In theory, the decider would then have no further need to exercise his discretion. In practice, however, neither this extreme nor any close variant of it has any interest for the incremental commitment case we are interested in, for reasons of excessive effort.

The trouble here is that commitment to a complete strategy is not one of the realistic options. One can typically change one's strategy as one goes along. One does not need to commit in advance and one cannot predict in advance one's subsequent acts with certainty (Brown, 1978). Perhaps one can define the option as a kind of increasingly fuzzy commitment as one looks further into the future.

#### ***3.5.1 Partial strategies.***

However, there is a wide array of weaker, partial characterizations of strategy, which can usefully be defined, evaluated and compared. At the lower end of the scale, which constrain discretion very little in the incremental commitment process, are broad precepts of war, such as "seek to retain the initiative" or situation specific statements of objectives. In the example of Appendix A, the guidance might take the form of "give first priority to preserving lives and resources, even if it means abandoning the military objective of interdicting enemy supply lines." Somewhat more specific would be to define a strategy in terms of the culminating choice (e.g., "surrender if necessary") or a desirable end position to be striven for (e.g., secure enemy rail depot).

Toward the other end of the scale would be set of contingency plans (permitting varying degrees of latitude), from doctrine, as it might appear in a field manual, to a complex computer program, of a type that might be used in "Star Wars." A major issue is determining how far in advance of the type commitments have to be made, the strategy is defined and/or evaluated. In particular,

how much is specified in the "courses of action," and how much introduced onto them as references to Standard Operating Procedures?

### *3.5.2 Contingent decision rules for incremental steps.*

Develop contingent decision rules for incremental steps, either to enhance expert or substitute for novice judgment. They can be developed well in advance (e.g., as computerized doctrine or training material) or immediately prior to engagement as part of the planning process. An implicit variant is to summarize a complete incremental strategy as a integral option (in terms of priorities, desired end point, nominal sequence, etc.).

### **3.6 Evaluating Incomplete list of options**

Part of the problem of evaluating strategies is that there are, in general, so many of them. In principle, there is nothing unacceptable in evaluating an incomplete list of options (initial actions or strategies). At least some such options can be eliminated and additional options can be introduced later, formally or informally. One useful strategy is to pick a small representative set of rather specific options that attempt to cover the full range of promising choices. The anticipation is that the one finally chosen will be a relatively minor adaptation of one of those originally selected acts, or that the comparison of the selected options will focus attention on a narrow range of possibilities.

In cases where possible initial acts are extremely numerous (or continuously variable rather than discrete), and those cases are common, one function of the decision analysis is to focus the decision maker's attention on certain "regions" of the possible decision space, for example, by discrediting large groups of possible actions. An alternative strategy is to specify the alternative initial acts in a broad inclusive way, such that any one "act" includes a whole class of more specific acts. If adequately carried out, such an analysis would yield a recommendation to look more carefully (informally or formally) at one of these groups. However, it is often difficult to carry out the analysis needed, for example, to quantify the necessary assessments if the conditioning initial acts are so broadly defined.

More concrete and clearly visualized analysis is possible, with the "incomplete list" approach noted above, but it is always possible that the best of all acts is not at all similar to the best one on the limited list compared (which may therefore be a poor guide).

### **3.7 Evaluate illustrative resulting sequence.**

Another kind of "incomplete evaluation" which can be used for a strategy or a single act--is to specify and evaluate only a single sequence of actions and reactions, pursuant to the choice in question. This would be based on a "modal" (most probable) or optimistic scenario. This may be of little help if there is a good chance the modal scenario does not occur--and again that might be a more prudent assumption for real war than for peacetime exercises. However, if several

broad strategies are concretized in this way, comparing the "most probable" implementations, may provide useful insight.

In the Appendix A example, evaluating one of the "defensive" courses of action might involve writing a "most likely" script for the next 72 hours culminating in breaking out to friendly lines. *[insert from p22 of 88 draft]*

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### **3.8 Alerting and tracking aids**

At each stage where an incremental commitment is to be made, the recognition required for RPD may be assisted by the display of useful cues. This may involve the periodic calculation and display of performance measures compared with expectations, to aid situation assessment.

One variant would involve tracking utility of present and possible future situations, using a general purpose evaluation model which does not change as the process unfolds, e.g., it uses the same standard broad attributes whose function and coefficients do not change. (The value table in the naval contingent decision aid called TACAID described in Brown, *et al.*, 1975 is an example.)

Another variant of such action-free feedback is the difference reduction heuristic used in business investment (Sterman, 1989), and in system dynamics (Senge, 1980).

### **3.9 Training aids**

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There are some promising variants of the decision theoretic paradigm, and the mode of their use presupposes that the incremental decider will use (or learn) an RPD cognitive process--and that he is well advised to do so. The role of the formal procedures is thus primarily to support or complement RPD.

#### *3.9.1 Enhancing recognition with simulated experience.*

The decider's RPD or other implicit decision rules may be developed through simulated experience. For example, deterministic or probabilistic simulation of action-response-evaluation sequences, generating plausible scripts may train RPD intuition prior to any commitment (more or less specific to the decision situation depending on lead time).

A specific, computer-aided technique, step-through simulation (Brown and Ulvila, 1978) permits a rich array of expert knowledge and imagination to be exploited in the development of training scripts.

\*\*\* [Muddling through, Lindblom]

## 4 INSTITUTIONAL CONSTRAINTS.

The institutional setting permitting (or forcing) incremental commitment may be a given of the situation, such that the decider only has to consider how to choose among these incremental options. Alternatively, there may be a higher order, institutional design problem, of how to constrain the dynamic process; for example, by specifying a schedule of decision points, with corresponding organizational responsibility, within which the decider(s) must do the best they can.

### *4.1 Illustrative setting: Nuclear dump site selection.*

The federal government is currently charged with selecting a nuclear dump site by the end of the century. Congress has [?] specified a firm sequence which requires the DOE to narrow down the choice from the whole continental US, first to major regions; then to some 250 areas; then to 20 potentially acceptable sites; then to 5 nominated; then to 3 recommended, and finally to 1 selected. Each such narrowing proceeds in a series of publicly reviewable, and essentially irreversible, "phases."

Within each such phase, the decision commitment process can be further constrained by institutional action (such as the establishment of binding guidelines on the steps to be followed in each narrowing). A live current issue is how much discretion to allow DOE program managers in site characterization activities which will lead--over the next six or so years--to the selection of one site from among three recommended. To what extent should the characterization plan be set once-and-for-all at the outset; as opposed to being revisable, either at the manager's discretion, or in a prestructured process?

This is quite a different issue from helping the manager exercise his options (whatever they may be) within a preset institutional structure. It can be argued that it is never in the interest of a decider to have his options constrained--though it may be in his interest to analyze his options as if they were constrained (e.g. as if he had a integral decision to make now). On the other hand his institutional masters may have their reasons to constrain him--for example Congress wishing to increase its control over the Executive Branch of government.

We are primarily concerned with providing analytic support rather than designing an incremental commitment process, i.e., we take the institutional constraints as given in this task.

## 5 CONCLUSION

### *5.1 Directions for research*

*[Move more material here?]*

There is no well-established methodology for supporting the incremental commitment process, nor theoretical foundations--descriptive, normative and prescriptive. The kind of thing needed to ultimately enhance real world practice includes

? promising analytic paradigms from the fusion of relevant normative (e.g., Merkhofer, 1977) and descriptive (e.g., Hammond, 1988) theory;

? case-testing of promising analytic variants (compared with current unaided practice), in naturalistic settings provided by our consulting practice; and

? a framework for matching aiding approaches to different types of incremental commitment tasks

Our current rather divergent ideas may pave the way, if appropriate, for subsequent more convergent basic research (for example, experimental research on variables found to be important), or the development of specific decision or training aids.

A taxonomy of decision situation characteristics relevant to the selection of an appropriate aiding strategy (such as delay between steps) can be built up inductively from the case-testing exercises.

Tentative guidelines on what aiding approach is most appropriate in what situation, may serve as hypotheses on which subsequent, more traditional experimental research may be based. No doubt the state-of-the-art of analytic aiding is enhanced in the case-testing process using the concept of "formative validation."

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[5.0]

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[fix numbering]

## **5.2 *Naturalistic Case-testing***

### **5.2.1 *Selection of cases.***

A desirable property of the findings of this project is that they be applicable ultimately to problems of practical concern. (However, in a military context the only truly naturalistic battle management cases would require a live war. Even field exercises have a significant contrived element, e.g., the absence of life-threatening danger.)

### **5.2.2 *Treatment of cases.***

Real incremental decision processes can be observed and tested for conformity to RPD and other cognitive models, such as those depending on schemas, and affective models, such those that are "enthusiasm-primed." One of the distinctive and convenient properties of incremental

commitment as a process is that the actual commitment of resources is largely available to inspection in a way that most cognitive processes are not.

A critical step is to evaluate the impact of the analytic "intervention" in terms of a decision maker's reaction and any indication of enhanced decision quality.

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## APPENDIX A

### A SPECIAL CASE: ARMY TACTICAL COMBAT

#### *Military operations case.*

In particular, battle management, traditional training<sup>1</sup> directs field commanders to evaluate a few "courses of action" and to commit to one of them.<sup>2</sup>

The common military practice of issuing orders in the form of a single "course of action" may give rise to rigid execution, even when flexibility is permitted, due to the expectation of having to justify departure from orders. The fact that situations involving potential incremental commitment are a source of below par performance in military command and control has been uncovered by previous studies. One report, based on substantial observation of navy and army exercises (DSI, 1989) states:

"The combined results of the four Army [studies] to date indicate certain trends concerning Division-level command and control performance: [the first of ten findings is that] there is a tendency toward "brittle planning," that is, developing only one option for dealing with the situation."

By "brittle planning" is meant selection of a single integral course of action that does not take advantage of opportunities for incremental adjustment in the face of unanticipated intelligence. The case that military action is generally undesirably inflexible is made more broadly in Foster (1988, Defense Systems Inc. 1989); and unaided intuition leads to escalation (Staw and Ross, 1989). Our own observation of exercises at Ft. Carson and Ft. Hood<sup>3</sup> confirms these findings. In particular, we found that tactical commanders fail to respond flexibly to changes in situation assessment.

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Much of the conduct of tactical warfare does have the incremental property. Major deliberate decisions are made, but they are rarely irreversible. The ebb and flow of battle calls for continuous reappraisal, adjustment and sometimes reversal. Intelligence, fire support, front-line and reserve infantry resources are continually being assigned and re-assigned.

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<sup>1</sup> See Page 24 of the Army Field Manual on Operations, FM 100-5, May 1986 Issue.

<sup>2</sup> However, alternative, more flexible approaches have been urged, such as the OODA feedback loop--observe, orient, decide, act--proposed by Col. John Boyd.

<sup>3</sup> Under the Headquarters Effectiveness Assessment Tool project

However, standard operating procedures, for example, as specified in Section IV of Field Manual FM 101-5 normally call for an essentially integral selection of a "course of action". The need to consider alternatives to conventional integral analysis of strategies is much increased as the complexity and tempo of modern warfare increases. *[expand?]*

#### A.1 An Illustrative Tactical Combat Case

In addition to examples from a variety of fields, we will use a specific hypothetical battlefield context as a source of illustrative material.

We suppose we are seeking to aid a U.S. division commander, typically a two-star general, during Air/Land Battle with Soviet-led forces.

He will generally conform to the military decision-making process specified in field manuals (though aids of the type we seek to develop may suggest changes). This is anchored to an essentially integral evaluation of a small number of "courses of action," of which the commander will select one, which become the bases for subsequent action by the commander and his subordinates. The evaluation might take 2-3 hours and involve evaluation of available intelligence and conferences with supporting staff.

However, his actual decision making is intrinsically incremental, in that, although there may be a clear cut initial intention, it will be executed in a series of steps, which can be modified or reversed as the situation develops. For example, he may have initially in mind to "stand and fight," and begin securing his perimeter, but seize an unexpected opportunity to "break-out."

Op Orders or plans are normally received from Corps HQ at intervals of 5-6 days, within which he will formulate his "course of action;" but he may receive an interim fragmentary order at any time sooner than that.

The form of his own action is to give orders to his own immediate subordinates through:

? operations orders every 2-3 days, covering all next command levels, including 6 brigade level line units, 5 staff aides plus chief-of-staff, 2 assistant commanders, and possibly foreign troops;

? frag orders at shorter intervals for specific purposes, e.g., to correct a previous op order aimed at a particular person; and

? informal continuing contact, especially with G-2, G-3 and other staff aides, including supervision of execution of earlier direction.

We would like to provide him with analytic tools that will help him to perform his decision-making role. These tools may consist of procedures (doctrine), analytic tools to be used during combat, planning aids in advance of the battle or prior training.

It may be that the strongest case for aid can be made at a higher, e.g., Corps level, on the grounds that the tempo at division level is too fast and the stakes too low to justify using up scarce time and resources on decision aiding. On the other hand, the rapid tempo may be what stands in the way of integral evaluation being appropriate. The accelerating pace of modern warfare is accelerating, at all levels, means that deciders do not have the luxury of "sleeping on it" every time there is an opportunity to change direction.

## A.2 Hypothetical Specific Scenario

In Central Europe in the well-studied region of the Fulda Gap, a U.S. infantry maneuver division has made a deep thrust behind the enemy lines pursuant to an operations order from corps command to capture a rail depot transfer post. The purpose is to relieve pressure on the corps due to the enemy's uninterrupted supply of material. Meeting this objective contributes to a higher order objective of regaining the initiative.

However, the effort has run into trouble. It has failed to achieve its immediate objective and is in imminent danger of being cut off from its own lines and being surrounded. One of its three brigades has itself been separated from the rest of the division. The division commander is faced with critical choices, offensive and/or defensive.

In the conventional evaluative mode, he is faced with the following plausible "courses of action:"

? Offensive:

continue mission and attempt to take objective;

break-out and attempt to return to friendly lines;

attack new objective with same purpose of interdicting enemy logistic lines.

? Defensive:

wait for relief/link-up from friends;

arrange reinforcements by air (either dropped or landing on some air-strip);

wait with a view to surrender, contingent on some damage threshold.

Our task in this case is to propose ways in which he might structure his incremental decision, as it unfolds, over a 2-3 day period, by the end of which some major resolution of the situation is expected to have occurred.

Often he will only realistically have one chance to switch courses of action before it is "too late," i.e., make incremental adjustments; for example, the airlift course of action may have to be abandoned as a result of unexpected bad weather.

In our tactical combat example, the divisional commander is free to exercise his discretion within the mission defined for him by the corps commander [*which is? needs to go into description of scenario*]. His actions, in turn will be expressed as tasks for his subordinates (who may have their own problems of incremental commitment in executing his orders). We are not concerned here with evaluating whether this institutional devolution of authority is appropriate.

In tactical combat, the planning horizon is largely a given for any practical decider. The corps determines what resources are available, with a decision cycle of 5-6 days; the division determines what will be done with the resources, with a 2-3 day cycle; then brigade determines how it will be done, with a 24-hour cycle, etc.

At each level, the cycle is defined only in terms of what the decider can execute. For a division commander it will consist primarily of orders he can give his immediate subordinates, typified by a written operation order.

At the battalion level, weapon employment (e.g., bombarding an enemy position) might be considered as culminating, whereas weapon deployment (e.g., putting artillery into place) would be preparatory. At the brigade level, weapon employment itself can be considered preparation for a culminating action (e.g., bombarding a position is preparation for capturing it). At the division level, capturing a position is preparation for, say, interdicting the enemy's supply lines.

*[Rework To Show Relevance Or Drop]* A division commander conventionally considers a close-in "area of influence," which he can immediately affect, usually defined in terms of the range of his artillery (say, 10-20 miles [?], i.e., it defines a class of decision executions (to fire weapons at targets within it). Beyond that is an "area of interest," with targets he expects to be able to "influence" within the next 2-3 days. *[Have I Got This Right?]*

This is the conventional planning horizon for a division commander. (The corps commander for example will have a planning horizon about twice as long.)

At any given time, a commander will be sharing his time between *[complete]*

### A.3 Current Action Evaluation Procedure

A major issue relevant to this paper is: How should the course of action be specified, given that the actual commitment of resources is fluid over time and can be reversed at very short notice? In this particular exercise, each course of action would typically be specified in the form of a single broad paragraph, typified by the following.

"CA 3 - Defend assigned sector with two brigades on line balanced to defend against an enemy main attack along either the OBERBEISHEIM-HOMBERG-BORKEN avenue or the OBERAULA- NEUKIRCHEN-TREYSA avenue with the reserve brigade located rearward in a position to block or counterattack an enemy penetration along either avenue of approach."

As is usually the case, this course of action is essentially a first step in what may turn out to be a incremental sequence, to be implemented according to Standard Operating Procedure.

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A military example might be making a strike on a target, where the, largely invariable, preparatory stages include: identifying target, tracking, arming weapon, firing; and the decision at each stage (possibly abandonment or changing target) is based on unfolding information.

*[Confusion predictable sequence of acts and of process—MAT]*

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Computerized "contingent action planning" procedures have been developed for military response to possible threats, for example, resulting in a decision rule of the "TACAID" type described in the ONR Operational Decision Aids project (Brown, *et al.*, 1975).

One could start with the same standard COA paragraph and structure, and elaborate it. This could be generalized into a computerized general doctrine which can be progressively tailored to a particular circumstance. In that case we would start with a doctrinal document, like a combat field manual. For the commander's decision, we would need to go back to the field manual which most closely covers the same ground; then see if we can turn it into a reasonably equivalent version consisting of "if--then" production rules. The conditions will typically be assessments rather than fact, or at least observations ("shoot if you see the whites of their eyes").

There may be some scope for plural production rules, i.e., defining a prescription at different levels, which may be produce inconsistent directives which need reconciling. The idea of a hierarchy of frames with slots that correspond to lower order frames is attractive here as an analogue to the hierarchical structure of command, i.e., from Army to Corps to Division etc. An assessment type of condition would be: to move the reserve up when the direction of the main enemy effort is clear with say 10% probability. The conditions may need to be expressed more fuzzily e.g., using verbal qualifiers like "likely." A doctrinal decision rule is: "don't attack unless you have a six:one force ratio advantage."

## APPENDIX C DIFFERENT TYPES OF SITUATIONS TO BE AIDED

There are a number of variants and circumstances of incremental decision commitment which have a significant bearing on the most appropriate decision-aiding technique.

*[Time stress]*

### Planning vs. Execution

A decision can only be considered as "made" or executed when there is a commitment of resources which cannot be reversed without some cost. A chess player who touches one of his pieces has executed a decision, if he plays by rules which require him then to move it; but he is only evaluating or planning the decision if he is playing by rules that allow him to change his mind. Either phase of decision making--commitment or evaluation--can be evolutionary or dynamic. In this paper we are concerned with aiding incremental execution--for which we may use planning tools (which themselves can be either integral or incremental).

*Preparatory vs. culminating phases of incremental commitment. [Drop section?]*

The distinction between planning and execution, as we are using the terms, should not be confused with the distinction between preparatory (e.g., toe in water) and culminating (e.g., plunge) phases of an incremental commitment cycle *[term?]*. Both can be planned or executed. The terms are relative, in that the whole "plunge" cycle, including preparation, can be considered preparation for higher level culminating action "get fit." The most useful characterization in any particular case will depend on the planning horizon of the decider--which he may or may not have control over (i.e., is the "plunger" considering his lifelong health strategy or only what he will do this morning?).

*Successive sub-division.* There is a distinctive and common situation is where the decision task is intrinsically integral, but the decider may choose to structure his decision process as if he were institutionally constrained to be incremental. This is where a single point is to be selected in a complex "option space," for example, allocating some scarce resource (money, fuel, ammunition) into a multitude of fine categories--by single decider (i.e., we are not considering the case where the budget is set by a hierarchy of authorities institutionally fixed).

Although the allocation could be made in one bite "bottom-up," (i.e., integrally specified all at once) he may choose to constrain himself to an incremental evaluation "top-down" (the total, then the major breakdowns, then the fine breakdowns are set) in order to break one big decision into manageable pieces. An unconstrained variant of this incremental evaluation is where the decider

is gradually making commitments as he sees fit; for example, making some minimal commitments early in the process, and adding to them selectively later. Thus an integral execution process can be evaluated as if it were constrained or unconstrained dynamic process.

The decision execution process is only incremental if each successive narrowing involves some commitment, whether partial or absolute. It will be partial, for example, if a division's fuel is tentatively allocated to Brigades, who count on it in their planning, but may find in the event that the allocation is shifted. Again, a partially incremental execution situation of this type may be evaluated as if it were constrained into a few discrete incremental steps, or as a single integral step (the converse of the earlier budget example).

*Predictability of structure of decision process.* Sometimes the decision commitment, though incremental, is well specified in advance, such that, in principle, each incremental step can be anticipated and possibly some operational aid developed for it. There is a single sequence giving rise to an end condition, as in putting your toe in the water through to taking the plunge. The incremental nature is due to the fact that the process can be halted (or decision changed) at any point in the light of incoming information.

In the more general case, the possible incremental options are not visualized with any precision in advance. Only very generalized guidance on their exercise is then possible. For example, in the development of a weapon system, there may be a incremental build-test-build-test sequence for which only generalized principles of engineering design can be proposed.

A simple variant is where there is a single decision variable like the amount of money to spend on a program and that amount is incrementally increased up to its final value (possibly with some backtracking). There maybe several such variables in a given decision situation, such as the extent to which a reserve battalion is committed.

A danger in designing incremental decision aids is of assuming the structure is predictable and fits one's preconceptions, engendered in training, about, for example, what the enemy might do. This could lead to the development of aids which are insufficiently flexible in the face of the impenetrable "fog of war."

*Clarity of ultimate choice.* However complex, fluid and ill-defined the bulk of the decision commitment process may be, the ultimate choice, toward which all preparatory effort is leading, may be sharply defined. For example:

? a swimmer taking the plunge;

- ? FDA approving manufacture of a new drug;
- ? feudal baron executing a prisoner by "death of a thousand cuts" (which might include second thoughts along the way, including binding up some wounds inflicted); [DROP?]
- ? DOE choosing a nuclear dump location.

In our combat example, the division commander originally identified a specific military objective, to capture a rail depot (probably specified in the corps commander's directions to him). In our scenario, continuing to pursue this objective has been put in question, as a result of encountering unexpected enemy resistance.

This type of situation fits our earlier characterization of preparatory and culminating phases of a decision commitment process.

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#### POSSIBLE ADDITIONAL MATERIAL

?Our basic hypothesis is that proficient management of this incremental task, in naturalistic settings, appropriately involves recognition-primed decision (RPD, Klein, 1989); but that the process can be enhanced by analytic evaluation or training.

This paper explores how such a process may be aided analytically, in a variety of settings.

Promising aids include:

- ? Concurrent evaluation of culminating commitments in conjunction with intuitive RPD on incremental steps;
- ? Contingent decision rules for incremental steps, either to enhance expert RPD or substitute for novice RPD;
- ? Probabilistic simulation of incremental sequences to train RPD intuition prior to any commitment; and
- ? Periodic display of performance measures, compared with expectations, to aid the situation assessment phase of RPD.