Midway Revisited: Detecting Deception by Analysis of Competing Hypothesis*

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Abstract
Historical accounts of military deception abound, but there are few historical accounts of counter-deception, and fewer operational theories. This paper describes a business process and semi-automated tools for detecting deception. Our prototype counter-deception business process starts with hypothesis generation. For tactical situations, this consists of automated course of action generation. Strategic situations rely on elicitation from analysts. Next, a Bayesian belief network is generated. This is followed by sensitivity analysis based on Bayesian classification. The result is a weighted list of possible observations that: (1) identify distinguishing evidence that a deceiver must hide and a counter-deceiver must uncover, (2) isolate local deception in intelligence reporting and sensing from global deception, and (3) identify circumstances when it might be fruitful to entertain additional hypotheses. We illustrate this model by describing how it could have been used by the Japanese Navy before the Battle of Midway to detect the American denial and deception tactics that allowed the U.S. Pacific Fleet aircraft carriers to ambush and sink four Japanese carriers.

Introduction

This paper considers counter-deception[1] from a psychological, rather than cultural perspective. First, we summarize the cognitive aspects of counter-deception. Next, we describe a process developed in the intelligence community called the Analysis of Competing Hypotheses (ACH). We describe how we correct ACH to account for cognitive factors that make people poor at detecting deception. We call this modified process ACH-CD. Then we describe semi-automated tools that demonstrate that ACH-CD is sufficient for counter-deception. Finally, we demonstrate how the modified process provides a basis for military counter-deception with a descriptive application to the battle of Midway, from Japan's perspective.

Why is Counter-deception hard?

Put simply, people are deceived because they do not systematically consider alternative explanations for the evidence they observe [JGJB2001, Heuer1981, Heuer1999; WB2002] and incorrectly weigh the evidence they do have [Dawes2001]. These

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behaviors occur because of memory limitations and realted reasoning heuristics that have evolved to deal with a high base rate world [GGK2002].The result is that people often dismiss important evidence, prematurely prune alternative hypotheses, and jump to conclusions. These make people and organizations easy to deceive.

Johnson et al. [Johnson2001] note that human evidential reasoning is mainly adequate for frequently experienced events. Reasoning heuristics that evolved to be cognitively efficient and effective in our high-base rate world often result in biased reasoning – grossly over or under estimating probabilities – when one is faced with low-base rate events such as deception [GT1999]. Since deception is relatively rare, it is not surprising that people are poor at counter-deception. Heuristics can result in the following analytic errors that hinder effective counter-deception:

- *Poor anomaly*[2] *detection:* Analysts miss environmental cues of anomalies, or prematurely dismiss anomalies as irrelevant or inconsistent with other intelligence;
- *Misattribution:* inconsistent or anomalous events are often attributed to collection gaps or processing errors, rather than to deception;
- *Failure to link deception tactics to deception hypotheses:* When they do notice anomalies, analysts usually fail to recognize anomalous evidence as indicators of deception;
- *Inadequate support for deception hypotheses:* Analysts fail to link their assessment of an adversary's deception tactics and goals to the adversary's strategic goals; i.e., analysts fail to test denial or deception COAs against all the available evidence.

Johnson et al. [Johnson2001] defined a four-part process for counter-deception analysis to address these four problematic heuristics. In this paper we describe how we adapted and augmented the "Analysis of Competing Hypotheses" technique for deception detection to address one part of this business process. We are also identifying and adapting useful theories or algorithms for the other components of the Johnson et al. model.

- Whaley & Busby's "Congruity Theory & Ombudsman Method" [WB2002] explicitly address the problem of *Poor anomaly detection* by identifying data collection techniques likely to surface anomalies related to denial or deception tactics.

- R. V. Jones's "Theory of Spoof Unmasking" [Jones1978, 1989, 1993] can be adapted to address the problem of *Misattribution*, i.e., to avoid attributing inconsistent or anomalous events to collection gaps or processing errors rather than to denial or deception tactics. Jones advocates analysis of anomalies through the use of multiple channels of intelligence (e.g., SIGINT, IMINT, OSINT) applied to anomalies, examined at various resolutions (both higher and lower). By comparing not only the expected means of these observations to base-rate data, but also the anomalous data's variance and skewedness, anomalies whose averages seem normal may be revealed as deceptive because the data do not vary, or vary in the normal directions, as do base-rate data. Finally, Jones advises "natural" or planned operational "experiments" that force the enemy to provide additional intelligence that will highlight possible denial or deception tactics.[3]

- We adapted Heuer's "Analysis of Competing Hypotheses" [ACH, Heuer1999] technique for counter-deception analysis to address the *Failure to link deception tactics to deception hypotheses.* This adaptation assesses the likelihood of indicator events and evidence across probable COAs, including denial and deception and separately assesses anomalies due to sensors, collection, or processing errors and anomalies due to denial or deception, i.e., the issue of "local versus global deception."

- Finally, Johnson et al.'s "Cognitive Model of Fraud and Deception Detection" [Johnson2001] organizes these four parts into a counter-deception business process (Figure 1) and addresses the problem of *Inadequate support for deception hypotheses.* Johnson et al. appreciate the need to address the sensitivities of hypotheses (COAs) to indicators (anomalous evidence) in order to effectively focus intelligence collections and operational intelligence experiments, to confirm suspicions of deception, and to reduce the uncertainties of deception estimates.

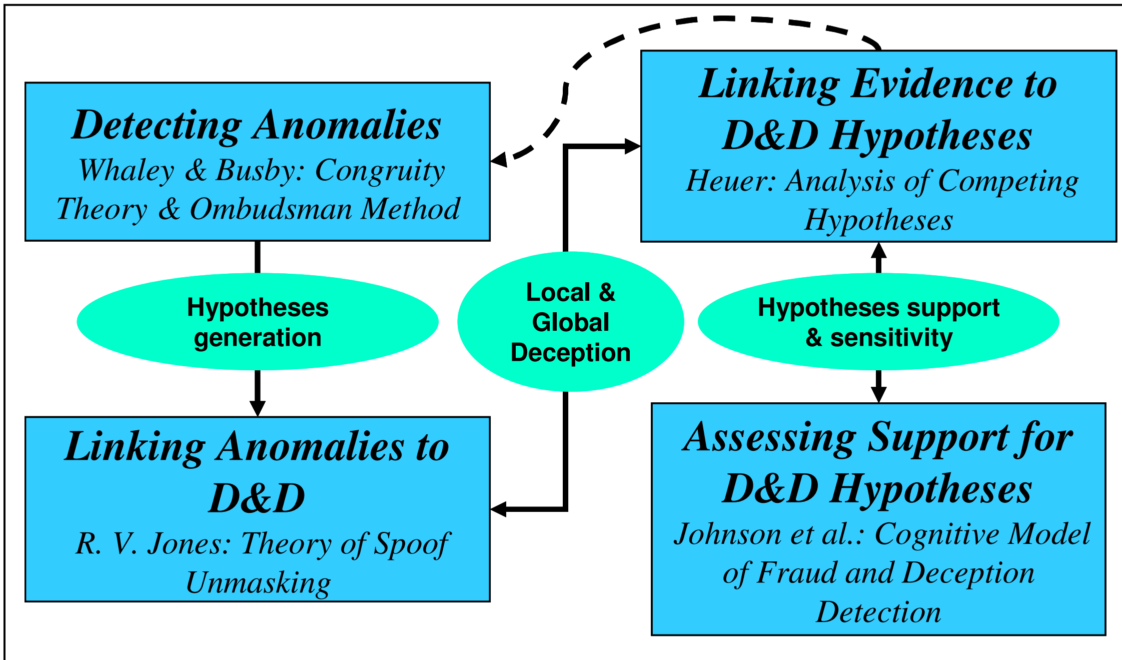

Figure 1: Counter-deception business process

What is an analyst to do?

Anyone who reads the newspapers knows that deception plagues the intelligence community. Over twenty years ago, Richards Heuer recommended analysis of multiple hypotheses as a counter-deception technique [Heuer1981]. Heuer [Heuer1999] later developed a protocol called Analysis of Competing Hypotheses (ACH) in part to address analysts' susceptibility to deception. ACH consists of the following steps:[4]

1. Prepare a matrix listing hypotheses vs. evidence.
    a. Identify the possible hypotheses to be considered.

   b. List significant observed evidence and assumptions for and against each hypothesis.
2. Draw tentative conclusions about the relative likelihood of each hypothesis, based on the evidence.
3. Analyze sensitivity of the conclusion to a few critical items of evidence.
4. Report conclusions.
5. Identify future observation that may indicate events are taking a different course than expected.

Put simply, ACH helps analysts to compare evidence, arguments, and assumptions (e.g., intelligence) to possible hypotheses (estimates of the situation or courses of actions). ACH ensures alternative hypotheses are equally and fully considered and that all the information value of the evidence and assumptions is applied to the hypotheses. Structuring helps analysts to probe and challenge evidence and assumptions and test the support for the hypotheses. ACH aids explicit questioning of both the credibility and the value of evidence. Heuer wrote:

> "Simultaneous evaluation of multiple, competing hypotheses … takes far greater mental agility than listing evidence supporting a single hypothesis that was pre-judged as the most likely answer. It can be accomplished, though, with the help of the simple procedures....The ACH procedure has the…advantage of focusing attention on the few items of critical evidence that cause the uncertainty or which, if they were available, would alleviate it. This can guide future collection, research, and analysis to resolve the uncertainty and produce a more accurate judgment."

Increasingly the major U.S. intelligence agencies have advocated ACH to enhance intelligence analysis and estimation. For example, the U.S. Central Intelligence Agency offers its analysts workshops on "Alternative Analysis" methods [DI2002]. The CIA re-published Heuer's *The Psychology of Intelligence Analysis* in 1999 and posted Heuer's book on the CIA's Internet website. Heuer's book is widely used in analyst training at the various national intelligence agencies. Morgan Jones, who learned ACH as a CIA analyst, featured the technique prominently in his book, *The Thinker's Toolkit: Fourteen powerful techniques for problem solving*, which is also cited widely in U.S. intelligence agency analyst training [Jones1998].

Adapting ACH for Counter-Deception

Our concern is that ACH can lead one to be *more susceptible to deception*. In particular, step 2 recommends weighing hypotheses in light of evidence (p(Hj|E), an heuristic Dawes [Dawes2001] notes as responsible for many of the reasoning errors he dubs "everyday irrationality." The problem with step 2 is that p(Hi|E) neglects both the base rates both of the evidence, p(E), and of the hypothesis, p(Hi). Neglect of base rates features prominently in many writings on evidential reasoning errors (e.g., Burns2004a, b, c). But more important for counter-deception reasoning, assessing (p(Hj|E) fails to direct the analyst's attention to the false positive rate of the evidence, p(E| not Hi).

Analysts' judgements are much more susceptible to deception if they do not normatively account for both p(E| Hi) *and* p(E| not Hi). Neglect of these base rates allows a deceiver to simulate evidence that is often associated with, but not necessary for, a particular course of action (hypothesis). Neglect of base rates can also foster the confirmation bias if analysts observe evidence that is consistent with more than one hypothesis.

To illustrate, consider a hypothetical strategic deception. Say we detect Krypton gas in some Middle Eastern country. This leads to a conclusion that the target country may have an active nuclear weapons program, since Krypton gas is a by-product of uranium enrichment. The argument might be summarized this way:

Detect Krypton
p(enrichment | Krypton) = high
➔ p(enrichment program) = high

Leading to:

p(nuclear program) = high

Intuitively appealing, but wrong. These two base rate errors are hard to avoid, due to our experience in high base rate worlds: first, generating hypotheses based on evidence "usually works" in our causally organized experience, and second, p(Ej|Hi) often provides a good approximation for p(Hi|Ej). ACH does not warn the analyst about either of these potential base rate errors. But the error most difficult to correct is failing to consider p(Ej| not Hi).

In our example, p(Ej| not Hi) is the probability of detecting Krypton gas when there is *no* enrichment activity. Depending on the situation, this probability might not be negligible. One use of Krypton gas is to test pipelines for leaks. If pipelines are common in the target country, then:

p(Krypton | not enrichment) = medium to high

Applying Bayes' rule with some representative numbers might lead one to determine that the detection of Krypton gas is not the definitive evidence of uranium enrichment that one thought. A possible deception hypothesis is that the target might simulate a weapons-grade enrichment program be intentional releasing Krypton, perhaps as an inexpensive deterrent to neighbors.

Summarizing, ACH offers a promising technique for counter-deception analysis, but some modification is needed so that hypothesis generation includes appropriate denial and deception COAs, and the ACH is used to elicit or estimate both p(Ej|Hi) and p(Ej| not Hi). We call our process, which is ACH with these modifications, "ACH-CD." The next section sketches how we partially automate ACH-CD for counter-deception decision support.

Automating ACH-CD

We have developed two computer programs that partially automate ACH-CD. One technique, described in [ES2003], is focused on tactical situations. It involves the following steps:

1. For a given situation, state one or more possible goal states.
2. Automatically generate hypotheses, in the form of state-based plans (courses of action), that can accomplish the goal state(s).
3. Automatically convert the course(s) of action (usually a contingency plan) to a Bayesian belief network.
4. Perform sensitivity analysis on the network by sequentially choosing possible outcome states and computing a factor of the optimal Bayesian dichotomizer (we omit the prior probability terms, as they are unnecessary and likely to be biased):

$$p(Ei|H)/p(Ei|\text{ not } H), \text{ for all states } Ei$$

The log of the state odds ratios provides an indicator of the impact of each state on the probability of an outcome (hypothesis) of interest, ordered by time of potential observation. This yields three sets of time-state intervals, representing: the states that must be hidden (denied), observations that have no probative value to the observer, and the states that one might simulate to deceive an adversary. Importantly, the list often will include negative information – states that are highly informative if one does NOT observe them. Reasoning about negative evidence is particularly problematic for people ("If the glove does not fit, you must acquit." – J. Cochrin).

The counter-deception analyst can use these results to direct collection to the most probative evidence. By knowing which states (observations) have no probative value, one can avoid the confirmation bias, basically seeing everything as support for one's preconceived notions about the adversary's intent. A deception planner can use the results of this system to determine which observations must be denied or have a plausible cover story. Strong indicators of an alternative hypothesis might be simulated to mislead the adversary.

Our second process is aimed at strategic deceptions that do not have a strong course of action analysis component, such as the question "does Iran have a nuclear weapons program?" This process starts with the elicitation of a set of mutually exclusive hypotheses, stated as True/False propositions. We automatically include a non-informative hypotheses, labeled "Other," so the list is exhaustive. This is followed by eliciting the items of evidence that are available. The most time consuming step is eliciting from the analyst(s) estimates of p(Ei|Hj) and p(Ei| not Hj) for all evidence Ei and hypothesis Hi. In practice, many of the elements of evidence will be uninformative (50-50) for some of the hypotheses.

Local and global deception

Our procedures also attempt to separate the effects of what we call "global and local deception." Global denial and deception is the term we use for the tactics of the deceptive adversary. Local denial and deception are the results of problems in a single event—observation interface: a broken sensor, an unreliable or dishonest agent, a poor observer.

Figure 2 shows how the evidence we observe is affected in three cases: no denial or deception, global denial, and global deception. In the cases of global denial and global

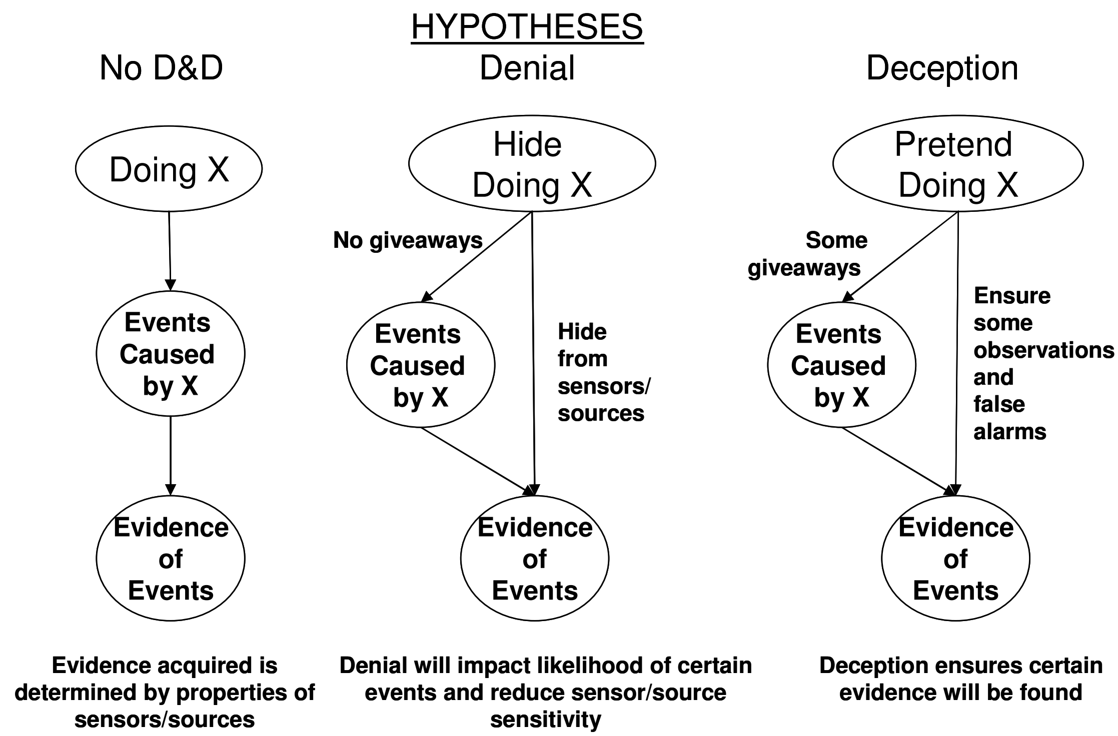

Figure 2: Relationships among events and evidence with no denial or deception, global denial, and global deception.

deception, *many* events must be hidden from observation (denial) and simulated or synthesized to be observed (deception) in order for the global deception to work. To generate effects consistent with the deceiver's deception goals and objectives, global denial and deception will impact many events, over time, through different means of collection.

Observations of a *single* event may be the same under local denial and deception or global denial and deception. An electro-optical IMINT sensor might fail to image a particular event because of fog, or a system failure in the sensor itself. This is local, not global, denial, but on a single image, it may be impossible to differentiate fog (local denial) from smoke (global denial). A HUMINT source may lie and fabricate a particular event to cause us to increase his payments. This is local, not global, deception, but in a report of a single event, it may be impossible to differentiate a greedy agent (local deception) form a double agent (global deception). At the level of the observations of *single* events, local and global denial and deception may have exactly the same impact. Local denial and deception, however, are unlikely to follow a consistent pattern across time, various events, and different collectors and sensors, whereas global denial and deception should be highly consistent over time, events, and observations.

While analysts cannot directly observe the events or the hypothesized COAs, analysts' experiences with the base rates of evidence over time, events, and sensors help them to anticipate and detect consistencies indicative of denial and deception COAs and allow them to distinguish these patterns of consistency from the patterns that would be expected for other COAs with no denial or deception. R. V. Jones's "theory of spoof unmasking" is aimed directly at this problem of differentiating anomalous intelligence that is just odd, from the anomalies that are indicative of denial and deception.

We address the differences between local and global deception by eliciting from analysts the events that would be caused by global denial and deception courses of actions, and eliciting the analysts' judgments about the likelihood of observations (evidence), given such events did, *and did not*, occur. Global denial and deception COAs will generate different assessments of the likelihood of events and of the evidence of those events than would local occurrences of denial and deception. In short, this technique depends on the base rates of multiple lines of evidence "looking different" to analysts, when faced with coordinated global denial and deception, than when faced with noisy, but uncoordinated, local denial and deception in the various event—observation channels. Our tools help analysts with counter-deception reasoning, but they do not eliminate the need for analyst experience and knowledge of denial and deception indicators and impacts.

Bayesian Belief Network

After the elicitation of COAs (including hypotheses of denial and deception COAs), related events, and expected evidence, a Bayesian belief network is created and the sensitivity analysis process described above is performed. The result is a list of evidence states that, if observed, would have the most significant impact on the likelihood of a given hypothesis.

The remainder of the paper describes how the Japanese Navy might have used the first of these methods, the ACH and ACH-CD counter-deception evidence elicitation and evaluation procedures, to improve their counter-deception assessments of American courses of action prior to the Battle of Midway. These techniques could have been used by the Japanese planners and intelligence analysts to assess the soundness of "Operation MI," the planned invasion of Midway Island and destruction of the U.S. Pacific Fleet. While our techniques that use Bayesian belief networks were not available in 1942, we show how they might have been used by the Japanese to assess the impact of the available evidence on their estimates of the enemy COAs bearing on the success of "Operation MI."

Applying ACH to military counter-deception

We illustrate how ACH-CD can address military counter-deception by examining the Japanese planning for the Battle of Midway from the viewpoint of the Imperial Japanese Navy (JN). In planning for this operation the JN conducted war plan reviews, table-top exercises, and naval exercises which shared the same steps as Heuer's ACH. Many of the tactical and operational problems that directly contributed to the defeat of the JN at Midway were specifically identified and discussed during these pre-battle JN ACH-like exercises, but the Japanese planners ultimately dismissed the identified problems, or met them with inadequate half-measures or inappropriate ripostes. Further, as JN planning assumptions were shown to be incorrect during the operation itself, the JN failed to replan or adjust its operations.

- JN planning hypotheses about enemy COAs (explicitly surfaced by the JN before the battle in ACH-like exercises):
  - *H1:* U.S. Pacific Fleet would be surprised, and would respond to the JN invasion of Midway, sending its remaining carriers to attempt to retake Midway.
  - *H2*: U.S. Pacific Fleet would be surprised, and would *not* respond to the JN invasion of Midway; letting Japan extend its naval base perimeter to mid-Pacific.
  - *H3:* U.S. Pacific Fleet would *not* be surprised, and its carriers will be waiting near Midway to attack the JN Carrier Battle Group (*Kido Butai).*

The JN received considerable intelligence, and had operational and tactical experience before the Battle of Midway, that was relevant to assessing these three hypotheses. (This evidence is summarized in Appendix 1). While historical accounts strongly indicate that the JN surfaced these hypotheses explicitly in these ACH-like exercises, and considered this evidence, the record is very clear that the JN never made an attempt to consider *all* the evidence and *all* of the hypotheses at the same time, as advocated by Heuer's ACH method. The hypotheses were raised and considered or dismissed serially and piece-meal. The JN planners never considered all the evidence as they assessed the strengths and weaknesses of these COAs and their planning assumptions. Much of the evidence reflecting JN tactical and operational weaknesses (particularly in intelligence, reconnaissance, and surveillance, ISR), while well-known in the JN, were nevertheless largely ignored in the design of "Operation MI." That is, the JN was suffering from what the Commander in Chief, Admiral Yamamoto, termed "the victory disease," the belief that their remarkable, seemingly unstoppable, string victories somehow absolved the JN from addressing their real and serious weaknesses.

In short, the JN failed to organize its ACH-like exercises into a single assessment of all the intelligence and evidence in planning Operation MI. Nor did the JN acknowledge the impact of important evidence that reflected directly on enemy COAs that would cause, at a minimum, potential problems in executing Operation MI, and at worst, defeat of the JN.

Had the JN simply drawn tentative conclusions using Heuer's ACH technique (see Table 1, top), that is, assessed the relative likelihood of each hypothesis based on the evidence they had available ($p(H_j|E_i)$), the JN might have estimated that it was perhaps as likely the U.S. Pacific Fleet carriers could be waiting to ambush the *Kido Butai* (H3), and possible that the U.S. carriers would *not* respond as the JN intended to Operation MI (H2), as was the hypothesis that the U.S. would respond as assumed to the invasion of Midway (H1). (This assessment is shown in Appendix 2.)

Table 1: Evaluating JN Hypotheses			
	ACH: Evaluating JN Hypotheses against Evidence (likelihood of hypotheses in light of evidence): $p(H_j \mid E_i)$ [See Appendix 2]		
Likelihoods	***H1:* U.S. will respond to JN invasion of Midway**	***H2*: U.S. will *not* respond to JN invasion of Midway**	***H3:* U.S. will be waiting near Midway**
In Favor	9	7	10
Opposed	9	6	7
Uncertain	0	5	1
Likelihoods	**ACH-CD: Evaluating JN Evidence against Hypotheses (likelihood of evidence in light of hypotheses): $p(E_i \mid H_j)$ & $p(E_i \mid \text{not } H_j)$ [See Appendix 3]**		
In Favor	8	9	9
Opposed	9	8	7
Uncertain	1	1	2

Had the JN assessed the evidence using the ACH-CD manner we recommend (see Table 1, bottom), that is, assessing the relative likelihood that the evidence would be observed given each of the hypotheses ($p(E_i \mid H_j)$ and $p(E_i \mid \text{not } H_j)$), the JN might have concluded that H2 *and* H3 were as likely as H1, and that the available evidence did *not* strongly support the JN favored COA, H1. (This assessment is shown in Appendix 3.)

To summarize, the JN might have done much to overcome the first two major hurdles impairing counter-deception analysis: *Poor anomaly detection* (missing anomalies or prematurely dismissing anomalies as irrelevant or inconsistent) and *Misattribution* (attributing inconsistent or anomalous events to collection gaps or processing errors, rather than to deception); had the JN used the ACH and/or the ACH-CD methods of assessment of the evidence and the hypotheses that had been surfaced at the various JN ACH-like exercises. Using either ACH or ACH-CD to review the JN planning assumptions against the available evidence, the JN planners would have had ample reason to re-examine the soundness of "Operation MI."

Furthermore, the JN might have been able to overcome the third major impediment to effective counter-deception analysis: *Failure to link deception tactics to deception hypotheses* (failure to recognize anomalous evidence as indicators of deception). That is, the events and evidence available to the JN before the Battle of Midway might have been assessed as possible indicators that the U.S. Pacific Fleet was using denial and deception tactics to conceal its true response to "Operation MI."

The U.S. Pacific Fleet *was* using denial and deception. The U.S. had reconstructed, through code-breaking and intelligence analysis, over 90% of the JN plan, and was able to forecast the exact location of the JN carriers over a week before the battle. The Midway defenders greatly increased counter-ISR operations to deny the JN current intelligence on defensive preparations. Further, the Pacific Fleet conducted a radio deception that successfully convinced the JN that the U.S. carriers remained in the Southwest Pacific following the Battle of the Coral Sea, and supported the U.S. deception cover story that the Pacific Fleet was unaware of Operation MI. In fact, Evidence reflecting specific denial and deception tactics used to conceal H2 or H3, and inconsistent with H1, are shown in Tables 2 and 3. Note that these indicators included negative evidence (e.g., *No U.S. aircraft carriers sightings in South Pacific after 17 May 1942; No apparent objectives for U.S. carriers in South Pacific, late May 1942*).

Table 2: Counter-Denial Indicators Available to JN Before the Battle of Midway

Denial Tactics	***Features of Denial Tactics***	***General Indicators of Denial Tactics***	***Indicators from Battle of Midway, May-June 1942***
Masking	Hide & conceal key characteristics, while matching another; eliminate characteristic patterns, blend characteristics with background patterns	--Key components missing, incomplete, or unaccounted; --High information value components unobserved where expected	- U.S. aircraft carriers undetected in North Pacific vicinity Hawaii or Midway, until 1-3 June 1942 - Aerial surveillance aircraft vicinity Midway all shot down
Repackaging	Add and change key characteristics; modify characteristic patterns, match an alternative component's characteristic pattern	--Excessive, inconsistent, or unexpected alternative components detected; --Too many of the wrong things	- U.S. aircraft carriers radio traffic prevalent in South Pacific - Operation K thwarted - Midway defenses & reconnaissance greatly enhanced, 3-4 Jun 1942 - Aleutian, other N. Pacific defenses *not* enhanced
Dazzling	Obscure key characteristics, saturate perception by adding over-powering characteristics; blur characteristic patterns to increase observer uncertainty	--Unexpected perceptual stimuli; --Atypical or uncommon patterns; --Unusual intensity, density, frequency	- Apparent U.S. carrier losses, e.g., Battle of Coral Sea - No apparent objectives for U.S. carriers in South Pacific, late May 1942.
Red Flagging	Display key characteristics ostentatiously, make high information value patterns conspicuously obvious, "wave a red flag;" generate observer suspicions	--Some, but not all, expected key components on obvious display; --Significant key components missing or unaccounted for	- U.S. submarines and scout aircraft at Midway deployed beyond normal operational limits, 1-3 June 1942. - U.S. aircraft carriers undetected in North Pacific vicinity Hawaii or Midway, until 1-3 June 1942

Table 3: Counter-Deception Indicators Available to JN Before the Battle of Midway			
Deception Tactics	*Features of Deception Tactics*	*Indicators of Deception Tactics*	*Indicators from Battle of Midway, May-June 1942*
Mimicking	Recreate or imitate a familiar characteristic patterns; copy alternative characteristics; create fictitious entities	--Observations inconsistent with expected numbers, patterns, configurations --Insufficient fidelity, inexplicable anomalies --Too many of the wrong thing	- U.S. aircraft carriers radio traffic prevalent in South Pacific - No U.S. aircraft carriers sightings in South Pacific after 17 May 1942 - No apparent objectives for U.S. carriers in South Pacific, late May 1942.
Inventing	Create new characteristic patterns with high information value; synthesize realistic indicators; invent key components	--Insufficient history, resolution, fidelity --Multi-dimensional "thinness" --Inappropriate consistencies --Exploitation of expectations, conditioning, reflexive control	- U.S. aircraft carriers radio traffic prevalent in South Pacific - No U.S. aircraft carriers sightings in South Pacific after 17 May 1942 - "Midway short on water"—"AF" short on water
Decoying	Create parallel characteristic patterns forming immaterial entities or indicators; provide realistic characteristic patterns to increase observer certainty	--Insufficient history or contiguity --Configuration & correlation anomalies --Multi-spectral anomalies or resolution "thinness" --Inconsistencies in spectral or dimensional resolution	- No apparent objectives for U.S. carriers in South Pacific, late May 1942. - U.S. aircraft carriers undetected in North Pacific vicinity Hawaii or Midway, until 1-3 June 1942
Double Play	Weakly & suspiciously suggest correct interpretation to reinforce incorrect interpretation; maintain or display real but suspicious characteristics to decrease observer acceptance	--Inconsistent history or timing of discrediting information --Discontinuous volume or intensity of disconfirming information --Inconsistent selectivity of information --Artificial consistency or uniformity of discrediting information	- U.S. radio traffic in North Pacific vicinity Hawaii, 1-3 June 1942

Tables 2 and 3 reflect the intelligence evidence available to the JN that was consistent with the possibility that the U.S. Pacific Fleet was using denial and deception tactics. We put this evidence of possible deception into a Bayesian belief network and linked the evidence to the relevant events (e.g., U.S. CVs in SW Pacific, US CVs in NW Pacific, Midway Island defenses enhanced, see Figure 3). We set the prior probabilities at H1=

70%, H2 = 20%, H3 = 9%, and H4 (Other) = 1%. We linked the events and hypotheses to the evidence using the ACH-CD procedures described above, using intermediate probabilities representative of a counter-deception analyst's expectation of those evidence items, given those events (True and False) and those COAs (True and False).

The evidence indicating possible denial and deception tactics is instantiated, as shown in Figure 4 by the gray boxes. For example, SIGINT intercepts indicated the US aircraft carriers (CVs) in the Southwest Pacific (SW Pac). JN ISR sighted U.S. CVs in SW Pac on 17 May, but not after. Midway Island aerial and submarine reconnaissance ranges were increased from 500 miles to 700 miles (MI_Recce_Expanded). The impact of these denial and deception indicators on the hypotheses reflecting the enemy COAs is dramatic. In Figure 4, the probability of H1 drops from 70% to about 14%, while H3 jumps from 9% to over 85%.

While the effect shown in Figure 4 is powerful, it merely shows the impact of isolating the evidence that was most indicative of possible American denial and deception tactics and then determining how that evidence could impact beliefs in possible enemy COAs. That is, the model shown in Figures 3 and 4 might have been used by a JN counter-deception analyst to make the case that the success of Operation MI was highly sensitive to indicators JN intelligence had noted of possible American denial and deception. Such indicators strongly support the possibility of COA H3, an American ambush. In making an overall assessment of the JN intelligence, all key intelligence items should be weighed along with these denial and deception indicators, in keeping with the ACH-CD procedure. Bayesian belief networks based on all the events, intelligence, and evidence available to the JN prior to the battle (Appendix 1) is shown in Figure 5, with the linking probabilities set using our ACH-CD process, with the prior probabilities for H1 through H4 as before. When all these evidence items are instantiated, as they might have been on the eve of the battle, the probabilities for the enemy (U.S. Pacific Fleet) COAs change dramatically (Figure 6, Table 4).

Table 4: Probabilities for Enemy Courses of Action before and after evidence available to JN before the Battle of Midway is considered using ACH-CD process.

Enemy (U.S. Pacific Fleet) Courses of Action	***Notional Prior Probability [Figure 5]***	***Probability after evidence is considered [Figure 6]***
H1: U.S. Pacific Fleet would be surprised, and would respond to the JN invasion of Midway, sending its remaining carriers to attempt to retake Midway.	70%	<2%
H2: U.S. Pacific Fleet would be surprised, and would *not* respond to the JN invasion of Midway; letting Japan extend its naval base perimeter to mid-Pacific.	20%	<1%
H3: U.S. Pacific Fleet would *not* be surprised, and its carriers will be waiting near Midway to attack the JN Carrier Battle Group (*Kido Butai*).	9%	98%
H4: Other COA	1%	<1%

Additionally, if the evidence available to the JN in April, May, and through 3 June 1942 are instantiated in the Bayesian belief network, the changing probabilities (Table 5) reflect how the accumulating intelligence might have shifted JN beliefs in the various enemy COAs in response to "Operation MI."

Table 5: Probabilities for Enemy Courses of Action based on evidence available to JN in April, May, and up to 3 June 1942.

Enemy (U.S. Pacific Fleet) Courses of Action	***April 1942***	***May 1942***	***3 June 1942***
H1: U.S. Pacific Fleet would be surprised, and would respond to the JN invasion of Midway, sending its remaining carriers to attempt to retake Midway.	69%	29%	<2%
H2: U.S. Pacific Fleet would be surprised, and would *not* respond to the JN invasion of Midway; letting Japan extend its naval base perimeter to mid-Pacific.	20%	1%	<1%
H3: U.S. Pacific Fleet would *not* be surprised, and its carriers will be waiting near Midway to attack the JN Carrier Battle Group (*Kido Butai).*	10%	70%	98%
H4: Other COA	1%	<1%	<1%

The pattern in Table 5 is symmetrical with the growing understanding of Japanese plans and intentions by the Pacific Fleet intelligence officers and commanders in Hawaii. By the end on May 1942, they had pieced together 90% of the plans for "Operation MI," had successfully portrayed the remaining US carriers as being in the Southwest Pacific through radio deception, and had planned their ambush for the Japanese carriers. When the *Kido Butai* arrived at Midway, the rest, as the saying goes, is history. Had the Japanese had better counter-deception business processes, it might not have been so.

Taken as a whole, both the ACH and ACH-CD techniques, which showed that H2 and H3 could not be ruled out as American COAs, and that H1, the enemy COA that the JN used as the basis for Operation MI was merely possible, not highly probable, as the JN planners believed. When denial and deception indicators are identified and considered in the Bayesian belief network, the impact of this intelligence on the probability of H3 is dramatic, and the possibility of an American deception and ambush becomes extremely difficult to ignore. Using a counter-deception business process to evaluate the sensitivity of possible enemy COAs to all the available evidence could have aided the JN planners to track the American deception and perhaps to avoid the utter debacle of "Operation MI."

In summary, the JN operational planners and intelligence analysts might have used Heuer's ACH, or our ACH-CD process, to review the available evidence and the planning assumptions underlying "Operation MI," as well as the other COA hypotheses that were surfaced in the JN ACH-like exercises. Using the ACH technique, they might have noted that the evidence available before the Battle of Midway was just as consistent with H3: the U.S. Pacific Fleet would ambush the JN carriers, as it was with H1, the hypothesis on which "Operation MI" was based (that the Pacific Fleet would be surprised by Operation MI and would respond on the JN time-table).

Furthermore, had the JN compared this evidence to the available indicators of American denial and deception tactics, they might have noted further support for the hypothesis that the U.S. Navy would not be surprised by Operation MI and was using denial and deception to cover a reposte. Had the Bayesian belief network technique been available, its use by a JN counter-deception analyst could have made a strong case that the possible American denial and deception indicators that had been observed before the Battle of Midway were strongly consistent with the hypothesis that the Americans were waiting to ambush the JN carriers.

Had the JN planners used the software tools we have developed to support a counter-deception business process, they would have been able to isolate those items of evidence that were most significant in supporting the various possible U.S. COAs. Such sensitivities can reinforce ISR operations and counter-planning. Such tools might also have aided the JN in the design of planned or natural operational-intelligence "experiments," as recommended by R. V. Jones's "theory of spook unmasking," to force the U.S. Pacific Fleet to reveal more evidence of its intentions and dispositions. For example, a realistic JN feint in the Coral Sea in late May 1943 towards New Guinea or Australia might have uncovered Nimitz's radio deception, and allowed the JN to realize that the U.S. carriers were no longer in the Southwest Pacific, despite strong, consistent SIGINT indicators that they were.

Conclusions and Areas for Further research

We have demonstrated how a counter-deception business process (Figure 1) based on ACH-CD can be applied to military counter-deception. We showed how evidence available to the Japanese Navy prior to the Battle of Midway, if analyzed using: (1) ACH or ACH-CD; (2) methods to isolate local and global deceptions; and (3) Bayesian belief networks; might have detected the American deception that allowed U.S. Pacific Fleet carriers to surprise, ambush, and sink four Japanese carriers threatening Midway Island.

We have developed a software system that automates ACH-CD and the techniques described above. Our effort now is on extending the core ACH-CD process to generate more complex courses of action and deal with "local versus global deception" in complex Bayesian networks. We are reviewing ongoing research on algorithms that detect anomalies that we might incorporate into the first step of our counter-deception business process and tools [e.g., Dragoni1996, Johnson2004, Santos2004, SWB1997]. We are also examining automated techniques that we might adapt to perform parts of the R. V. Jones process of "spoof umasking," i.e., identifying anomalies that are related to possible deception tactics.

We are building an interface to our deception planning system that will help users easily create realistic domain descriptions. The deception planning system will fill in plans and create COAs as alternatives. On the back end, the planning system suggests deception tactics to keep an adversary from recognizing the true plan (dissimulation) and ways to give the adversary a false apprehension of reality (simulation). A temporal model generated with the alternate courses of action will be an important input to this process.

The deception planning system will be extended to counter-deception planning using AP's counter-planning process.

We have been conducting experiments to assess how well this counter-deception business process can: (a) help plan deceptions, and (b) detect deceptions. As indicated above, the system has been successful in determining previously unknown details of how historic deceptions have succeeded, such as the Battle of Midway, and in reflecting how better assessment of intelligence, using a explicit counter-deception business process, can increase the likelihood of detecting and characterizing military deceptions.

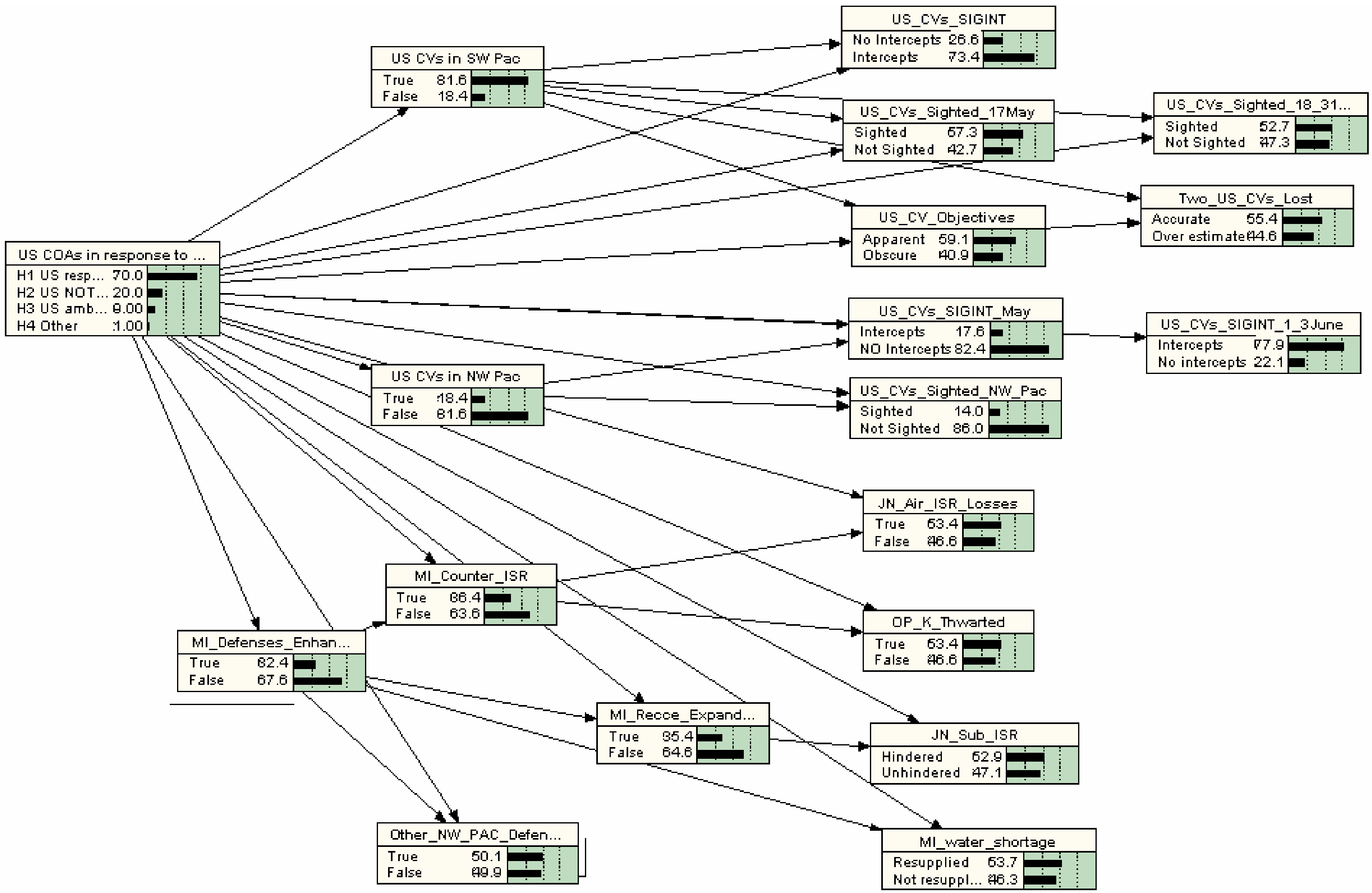

Figure 3: Bayesian belief network reflecting events (center) related to Japanese hypotheses (left, enemy courses of action, COAs) in response to "Operation MI" and available intelligence evidence (right) of possible American denial and deception tactics linked to those COAs and events.

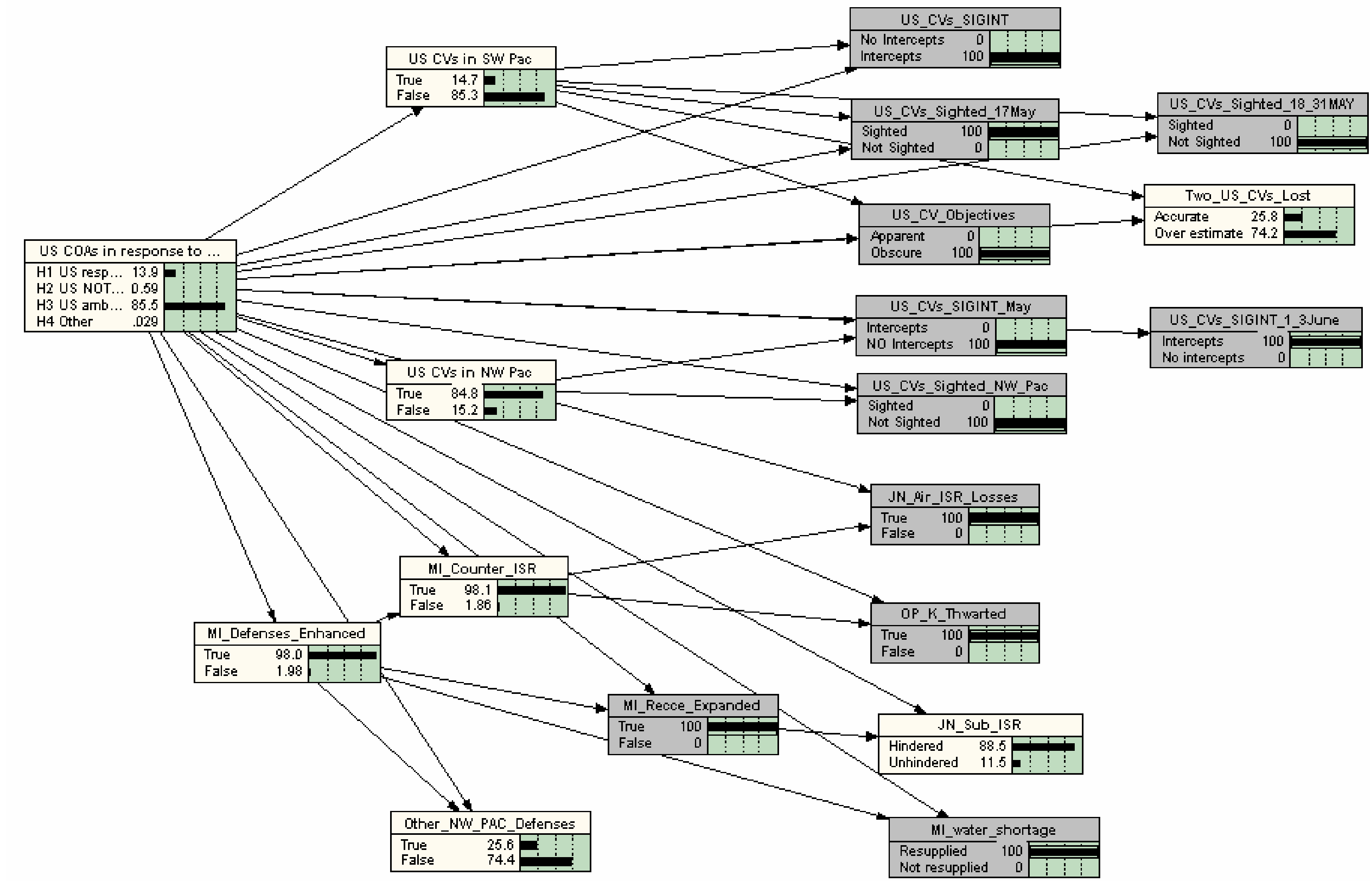

Figure 4: When evidence of possible denial and deception (gray boxes), observed by the JN prior to the Battle of Midway, is instantiated in the Bayesian belief network, it strongly supports enemy COA *H3:* U.S. Pacific Fleet would *not* be surprised, and U.S. carriers will be waiting near Midway to ambush the JN Carrier Battle Group (*Kido Butai).*

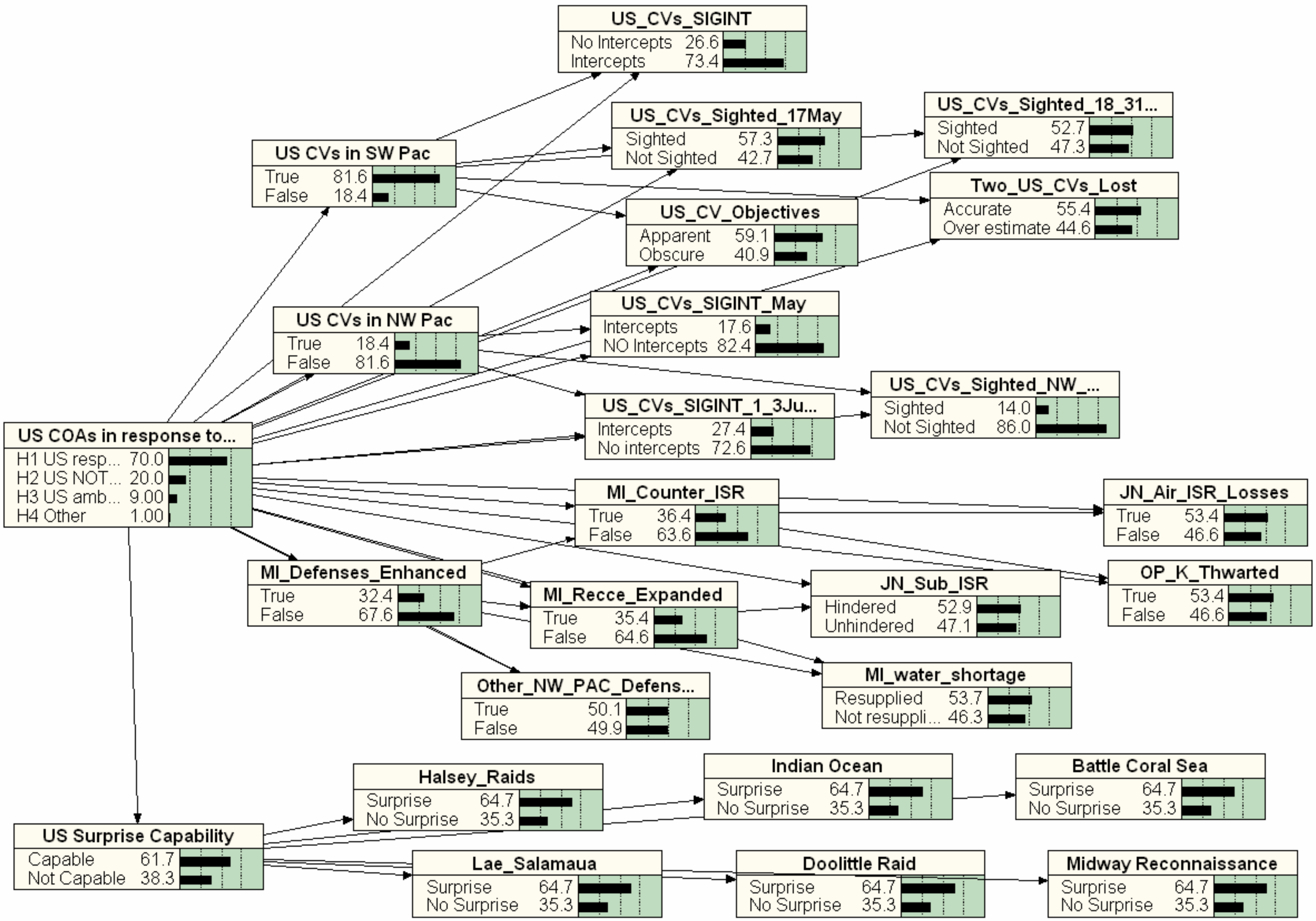

Figure 5: Bayesian belief network showing the events, intelligence, and evidence obtained by Japanese Navy before Battle of Midway (based on Appendix 1) and prior probabilities for enemy (US) COAs, favoring COA H1: U.S. Pacific Fleet would be surprised, and U.S. carriers would respond to Japanese attack on Midway Island.

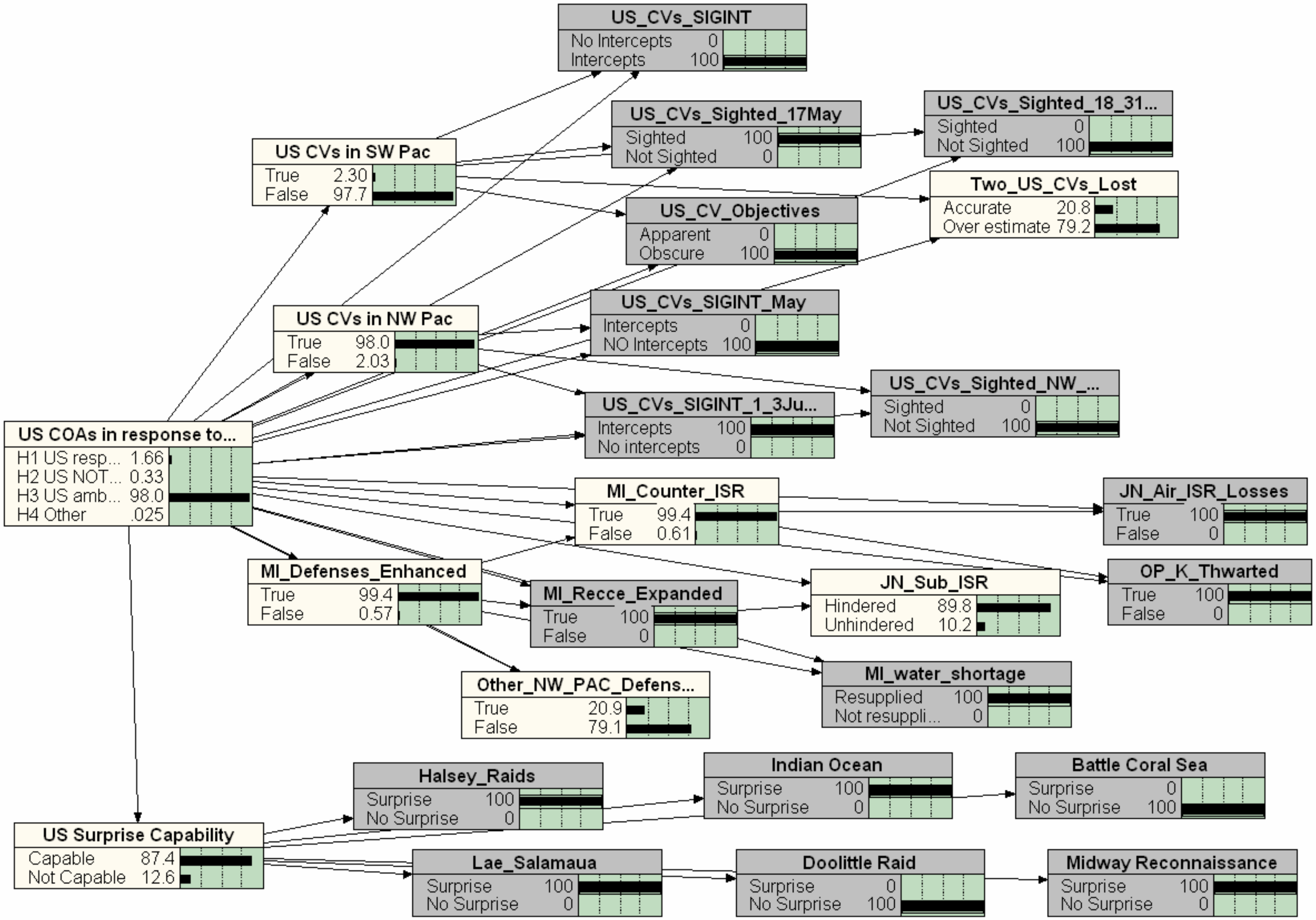

Figure 6: When evidence, observed by the JN prior to the Battle of Midway (gray boxes), is instantiated in the Bayesian belief network, it strongly supports enemy COA *H3:* U.S. Pacific Fleet would *not* be surprised, and U.S. carriers will be waiting near Midway to ambush the JN Carrier Battle Group (*Kido Butai)*.

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Footnotes

[1] In this paper, the term counter-deception means detecting or recognizing a deception. Note that successful counter-deception does not necessarily imply that one knows the adversary’s true course of action. We use the term deception to include denial, or hiding, which we consider a component of deception behavior.

[2] We do not intend to imply that counter-deception is mainly a process of anomaly detection, in the statistical sense. We use the term “anomaly” to denote evidence that is not consistent with current beliefs about the state of the world or the predicted actions of an adversary.

[3] At the Battle of Midway, the Americans used an operational-intelligence experiment to confirm that the main Japanese target was Midway Island. Midway defenders signaled Hawaii in the clear that the island was short of water. Japanese SIGINT picked up the bait and alerted Tokyo that “AF” codename of the main operation, was short of water, linking the bait to the Japanese planning traffic the Americans had already intercepted.

[4] Here we simplify and slightly reorder the steps. See Heuer1999 for the original eight-step formulation.

Appendix 1

Events, Intelligence, And Evidence Obtained by JN Before the Battle of Midway	
Date	*Events and evidence*
Jan-Mar 1942	U.S. carrier raids against the Marshalls, Rabaul, Wake, Marcus Island, and eastern New Guinea: Indicates ineffectiveness of JN reconnaissance and warning intelligence.
10 Mar 1942	U.S. carrier aircraft surprise ADM Kajioka's Japanese Landing Forces at Lae and Salamaua in the Solomon Sea: U.S. carriers able to position themselves to ambush the JN landing forces and escape. Indicates effectiveness of U.S. intelligence and reconnaissance.
2-5 Apr 1942	Naval General Staff and Combined Fleet Planning Debate: JN war-gamers assumed U.S. forces would conform to JN plan and timetable (H1). No efforts to war-game a delayed U.S. response, after Japanese fleet had departed (H2). No efforts to war-game U.S. surprise at Midway (H3). No JN estimates of possible impacts of a U.S. victory (or draw) at Midway on U.S. or Japanese strategy, operations, or morale. Indicates narrow assumptions governing JN planning.
5-9 Apr 1942	*Kido Butai* Surprised in Indian Ocean: Detected by land-based reconnaissance and bomber aircraft, and surprised by British cruisers DORSETSHIRE and CORNWALL, carrier HERMES and destroyer VAMPIRE. Indicates weak JN carrier-based counter-surveillance, intelligence, and reconnaissance.
18 Apr 1942	Sharp increase in U.S. Navy radio communications near homewaters: JN traffic analysis correctly indicate Doolittle Raid.
1-6 May 1942	Combined Fleet War Games: raise the contingency that U.S. carrier task force might appear on *Kido Butai* flank during scheduled air attack on Midway: JN umpire negates effective contingency response planning.
31 May - 3 Jun 1942	U.S. units occupying French Frigate Shoals: Operation K forestalled (plan for JN subs to rendezvous at French Frigate Shoals to refuel seaplanes flying from Wotje, to reconnoiter Pearl Harbor)
7-9 May 1942	JN SIGINT: detected U.S. carrier force in the Coral Sea prior to Operation MO--Battle of the Coral Sea.
7-9 May 1942	JN report both U.S. carriers (LEXINGTON and YORKTOWN) sunk in Battle of the Coral Sea: JN Naval Staff assumes U.S. has two remaining carriers (HORNET and ENTERPRISE).
15-16 May 1942	JN air reconnaissance: Identifies HORNET and ENTERPRISE in Solomons Islands.
May-3 Jun 1942	JN COMINT: Identifies HORNET and ENTERPRISE radio communications in South Pacific. JA Naval Staff concludes U.S. has not detected JN Midway intentions (Operation MI).
18-20 May 1942	JN COMINT: Reports Midway radio indicates island short on water, Hawaii will re-supply.
May 1942	JN Air Reconnaissance: All long-range Japanese aerial reconnaissance missions to Midway are destroyed.
24 May 1942	JN Combined Fleet Estimate: At final Table-top Maneuvers ADM Ugaki (Yamamoto's Chief of Staff) states: "It is hard to make accurate judgment of the next enemy move…but according to newspapers they were reported to be heading for Australia. At present, the whereabouts of two enemy carriers is unknown—either in Australia or Hawaii." Failure to include all possible hypotheses (e.g., H3).
24 May 1942	JN Combined Fleet Estimate: JN intelligence on Aleutians was abysmal, out-of-date, vastly over-estimating U.S. ground forces, under-estimating naval forces, and completely ignorant of land-based air forces.

Events, Intelligence, And Evidence Obtained by JN Before the Battle of Midway	
Date	*Events and evidence*
29-31 May 1942	JN Reports: U.S. reconnaissance arc extended from 500 to 700 miles from Midway. U.S. submarine transmission indicated JN Transport Group had been discovered west of Midway. U.S. Pacific Fleet radio traffic and ratio of urgent messages greatly increased in Hawaiian and Alaskan waters: JN indications of U.S. readiness and preparedness for Operation MI.
2 Jun 1942	*Kido Butai* failed to receive urgent transmission: JN Naval Staff estimates that Americans had discovered Midway operation and might be sending carriers to ambush *Kido Butai*.
3 Jun 1942	*Kido Butai* estimate: "It is not believed that the enemy has any powerful unit, with carriers as its nucleus, in the vicinity."
3 Jun 1942	U.S. Midway-based PBY scout aircraft: Spot JN Invasion Force where predicted (24 hours before Japanese expected to be detected).
0820 4 Jun 1942	JN Scout aircraft: Reports U.S. carriers within 150 miles of *Kido Butai.*
1024 4 Jun 1942	U.S. carrier dive bombers sink three *Kido Butai* carriers within minutes, later sink fourth.

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Appendix 2

Evaluating JN Hypotheses supported by Evidence (likelihood of hypothesis given evidence): $p(H_j\|E_i)$			
	Hypotheses		
Evidence	*H1:* U.S. will respond to JN invasion of Midway	*H2*: U.S. will *not* respond to JN invasion of Midway	*H3:* U.S. will be waiting near Midway
U.S. carrier raids: Indicates ineffectiveness of JN ISR.	N	Y	Y
U.S. carriers surprise Landing Forces: Indicates effectiveness of U.S. ISR.	N	N	Y
Kido Butai Surprised in Indian Ocean: Indicates ineffectiveness of JN ISR.	N	Y	Y
JN traffic analysis correctly indicates Doolittle Raid.	Y	Y	N
U.S. units occupying French Frigate Shoals: Operation K forestalled	N	?	Y
JN SIGINT: detected U.S. carrier force in Coral Sea	Y	N	N
JN Naval Staff assumes U.S. has two remaining carriers	Y	Y	N
JN air reconnaissance: two U.S. carriers in Solomons Islands.	Y	?	N
JN COMINT: two U.S. carriers in Solomons Islands.	Y	?	N
JN COMINT: Midway short on water, Hawaii will re-supply.	Y	N	?
All Japanese aerial reconnaissance to Midway destroyed.	N	?	Y
JN Combined Fleet Estimate: "two enemy carriers—either in Australia or Hawaii."	Y	Y	N
JN intelligence on Aleutians out-of-date & inaccurate	Y	Y	Y
JN indications of U.S. readiness and preparedness for Operation MI.	N	N	Y
JN Naval Staff estimates: Americans had discovered Midway operation, might ambush *Kido Butai*.	N	N	Y
Kido Butai estimate: no enemy carriers in vicinity.	Y	Y	N
U.S. Spot JN Invasion Force where predicted	N	?	Y
U.S. carriers within 150 miles of *Kido Butai.*	N	N	Y
Totals	Y 9 N 9 ? 0	Y 7 N 6 ? 5	Y 10 N 7 ? 1

Appendix 3

Evaluating JN Evidence and Hypotheses (likelihood of evidence given hypothesis-True and hypothesis-False): $p(E_i \mid H_j)$ & $p(E_i \mid {\sim}H_j)$			
	Hypotheses		
Evidence	*H1:* U.S. will respond to JN invasion of Midway	*H2*: U.S. will *not* respond to JN invasion of Midway	*H3:* U.S. will be waiting near Midway
U.S. carrier raids: Indicates ineffectiveness of JN ISR.	N	N	Y
U.S. carriers surprise Landing Forces: Indicates effectiveness of U.S. ISR.	N	N	Y
Kido Butai Surprised in Indian Ocean: Indicates ineffectiveness of JN ISR.	N	N	Y
JN traffic analysis correctly indicate Doolittle Raid.	Y	Y	N
U.S. units occupying French Frigate Shoals: Operation K forestalled	N	Y	Y
JN SIGINT: detected U.S. carrier force in Coral Sea	Y	Y	N
JN Naval Staff assumes U.S. has two remaining carriers	Y	Y	N
JN air reconnaissance: two U.S. carriers in Solomons Islands.	Y	Y	N
JN COMINT: two U.S. carriers in Solomons Islands.	Y	Y	N
JN COMINT: Midway short on water, Hawaii will re-supply.	Y	Y	?
All Japanese aerial reconnaissance to Midway destroyed.	N	N	Y
JN Combined Fleet Estimate: "two enemy carriers—either in Australia or Hawaii."	Y	Y	N
JN intelligence on Aleutians out-of-date & inaccurate	?	?	?
JN indications of U.S. readiness and preparedness for Operation MI.	N	N	Y
JN Naval Staff estimates: Americans had discovered Midway operation, might ambush *Kido Butai*.	N	N	Y
Kido Butai estimate: no enemy carriers in vicinity.	Y	Y	N
U.S. Spot JN Invasion Force where predicted	N	N	Y
U.S. carriers within 150 miles of *Kido Butai.*	N	N	Y
Totals	Y 8 N 9 ? 1	Y 9 N 8 ? 1	Y 9 N 7 ? 2