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Response to Discussion by A. H. Welsh on the AF 447 Paper

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I thank Professor Welsh for his very kind comments about the AF 447 paper. He makes a number of excellent points. One is that Bayesian analysis is a tool and that must be used carefully and thoughtfully in order to obtain good results in a complicated problem such as the search for AF 447. While this is true, the use of Bayesian analysis is required to incorporate the necessary subjective judgments into the analysis of the AF 447 search. As Welsh notes, Bayesian analysis allowed us to propagate these judgments and uncertainty distributions into the probability distribution on the location of the wreck in a logical and correct fashion. Classical statistics does not provide a framework for doing this. Bayesians should celebrate this advantage.

The power of Bayesian analysis as a tool is further illustrated by the U.S. Coast Guard's Search and Rescue Optimal Planning System (SAROPS). SAROPS is a Bayesian search planning program used by the Coast Guard every day for planning searches for people and boats lost at sea. It is run by Coast Guard officers who are trained to use the program but are by no means experts in Bayesian analysis. The Coast Guard considers it one of their best operational computer programs.

Welsh suggests that the use of data from nine somewhat similar situations casts doubt on the claim that the use of subjective probabilities is required for the AF 447 analysis. However, the availability of this data does not mean we could reasonably have produced the AF 447 distribution without the use of subjective probabilities. The use of subjective probabilities is one characteristic that distinguishes Bayesian statistics from classical statistics where decisions are supposed to be made solely on the basis of objective information and scientific analysis. It seems to me that Bayesian analysis is uniquely suited for tackling complicated problems of this sort.

Welsh asks two interesting questions: (1) What would be the result of a Bayesian version of the reverse drift analysis (performed by the drift group) that produced the rectangle for the fourth unsuccessful search? (2) What is the correct way to handle the uncertainty about whether the underwater locator beacons functioned or not?

Question (1) is answered in the paper. The process of producing the reverse drift scenario distribution was our attempt to do the reverse drift analysis in a Bayesian fashion accounting for the uncertainties in the winds, currents and drift behavior of dead bodies. This analysis produced a distribution that spread over a very large area of the ocean. When we intersected this distribution with the 40 NM circle, we obtained the distribution shown in Figure 3 of the paper. In retrospect, it appears that this would have been a pretty good prior distribution for the location of the wreck before any search took place. By comparison, the rectangle produced by the drift group is in a very low probability region of this distribution. The "uncertainties in the uncertainties" in the reverse drift scenario distribution would have given us pause in recommending it as the sole method of computing the prior location distribution. In computing this distribution, we used the drift group's choice for the best current estimate, but there were other possibilities that were reasonable too. The estimate provided only a mean current without any stochastic component to it. We had to add uncertainties to the mean in order to obtain a stochastic process for the currents. These uncertainties coupled with the large spread in the resulting location distribution left us with low confidence in this scenario.

Question (2) is also answered in the paper. At the end of Section 4.6, we note that "a better way to handle the doubts we had about the beacons would have been to compute a joint distribution on beacon failure and wreck location. The marginal distribution on wreck location would then be the appropriate posterior on which to base further search." After the unsuccessful passive search, the joint posterior distribution would have reflected correctly both the possibility that beacons were not working and that they were working

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but not detected. The marginal distribution on beacon failure would have provided a quantitative estimate of the probability of beacon failure. Providing the joint distribution would have been better than providing the BEA with two distributions, one assuming the beacons functioned and one assuming they failed.

The passive search did indeed cover the location of the wreck. If the beacons had been working properly, it is highly likely that the passive acoustic search would have detected them and that Bayesian analysis and the authors of the AF 447 paper would never have been involved in the search.