

The Amateur Search

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Abstract

In the days that followed Jim's disappearance at sea, his family, friends and colleagues came together in a remarkable effort to help find him. The group gathered, analyzed and filtered information from many sources. In concert with the Coast Guard, the results were used to focus the search in the places where Jim and his sailboat Tenacious were most likely to be.

The scope and breadth – indeed, the very existence – of this amateur search effort reflect Jim at his best. The group was at first composed of those whose lives he had touched directly, who used skills and knowledge he had helped them to gain in hopes of finding him. As time passed, others joined in who were inspired by the unfolding story. In the end, thousands came together to search for Jim.

1. Introduction

There have been a number of articles that describe Jim Gray's disappearance and the ensuing search for him – for example, [Hafner 2007] in the immediate aftermath of his disappearance and [Silberman 2007] some months later, providing a more comprehensive picture. In addition, the Tenacious Search blog [Tenacious] offers a detailed view of the search effort as it unfolded.

Like those articles, this one is mostly about the amateur search – the impromptu effort by Jim's friends and colleagues to find him or to figure out what happened to him. Unlike those articles, this one is written from the perspective of a participant in the search, and I hope to capture some sense of how the group formed, how we worked together and what we learned during those weeks in early February 2007.

Much has been made of the amateur search, and of similar efforts like those to find the Kim family [Kim] and Steve Fossett [Fossett]. Despite the allure of the amateur stories, most search and rescue efforts are run by professionals. The search for Jim was no exception. In our efforts to find him, the amateur search community worked closely with the US Coast Guard.

2. Jim's Disappearance

On January 28, 2007, Jim Gray took his 40-foot sailboat Tenacious on a single-handed cruise from San Francisco Bay to the Farallon Islands off the California coast. He planned to scatter his mother's ashes at sea.

Tenacious did not return to port.

3. The First Week

When Jim's wife, Donna Carnes, did not hear from him that evening as expected, she contacted the US Coast Guard, which launched an air and sea search to locate his sailboat.

At the same time, word circulated quickly among Jim's friends and colleagues that he was missing. At first, the email messages were expressions of concern for Jim and his family. An idea quickly occurred to several different people, though: Jim had

spent much of his career working on remote sensing projects. Could we use tools like satellite imagery to look for him at sea?

By January 30, there was a fast-moving effort underway to collect and analyze imagery that might show the location of Tenacious. The informal network among Jim's colleagues spanned organizations including Microsoft, Google and NASA, all of whom brought resources to bear in the first few days of the search to collect that imagery.

4. Organization

Early in the amateur search, Joe Hellerstein at Berkeley set up a blog [Tenacious] to serve as a clearing house for information on the search. An enormous number of people were interested in what we were doing, and a large number were participating. The blog made it much easier to keep everyone up to date.

Much of what we were doing, though, was not yet ready for public consumption. There was technical and scientific chatter among researchers and back-room politicking to get access to more data that might help the search. Only a small fraction of our conversations were on the blog.

By the end of the first weekend of the search, several dozen people were actively working together. The email Cc: lists were steadily growing and individuals were forwarding copies of messages from one collection of people to another. Communication was becoming a real problem.

Just as that situation was becoming critical, a handful of the most active participants agreed that we needed to form teams with clear leaders to concentrate on specific tasks. Over the course of about one day, that happened. There were no battles for leadership roles; people with the right skills who were willing to do the work quietly stepped up. Of course, we all knew the stakes, so it is not exactly a miracle that this transition went smoothly, but it was still unusual to see an organizational structure appear on demand with no infighting.

This transition was a critical one in the amateur effort. It allowed us to concentrate people and resources on crucial work, and to eliminate distraction. It permitted groups to work together well by setting up clear lines of communication. It established a hierarchy that could work productively with the Coast Guard, so that we supported and augmented the professional search.

As others have noted, the teams that formed included people from a variety of organizations – commercial, academic and governmental. It is true that competitors in the real world, like Microsoft and Oracle, worked together closely on the search. To those of us involved, was not surprising. We all knew Jim.

5. Imagery

Finding useful satellite imagery was difficult. We needed recent imagery of the sea off the coast of California. Most commercial and research satellite operators are more interested in land than in open water. The actual strip covered by an imaging pass of an orbiting satellite is remarkably narrow, and the area of ocean that

interested us was wide. Retargeting satellites to cover the area we cared about was expensive and, more importantly, slow.

The technical details of the imaging satellites also mattered a great deal. Images from a sensor with 5m or coarser resolution would need enhancement, for example using multispectral techniques, to detect a boat that was just about one pixel wide. Depending on the spectral range captured by the sensors, the boat might not show up against the background of the sea surface. In addition, different wavelengths are filtered and reflected differently by the atmosphere, so wind or cloud cover, among other things, could hide the sea surface from the camera.

Even if we could get images that contained the boat, we still had to spot it. A number of image processing experts from the Jet Propulsion Laboratory, Johns Hopkins University and elsewhere began to write software to capture, process and analyze the images. A team at Amazon arranged for a large-scale parallel and redundant manual scan by humans of the pre-processed images using the Mechanical Turk system to look for the boat.

6. Drift

The passage of time posed a variety of problems for us. Wind, currents and the interaction of hull and water, plus the possibility that Tenacious may have been under power for some period, meant that we were chasing a moving target. Image capture and processing took time. If we captured the craft in an image, it would have moved by the time we detected it. In order to choose locations to image and to target for aircraft search, we needed to be able to predict the movements of the boat on the water.

To solve this problem, three different drift modeling teams formed. They began with models that had been developed for research on ocean prediction, and used data collected from operational Navy models, coastal current radar and a variety of other oceanographic sources. The teams validated their results using the tracks of actual drift buoys dropped during the search by the Coast Guard for the purpose.

The validation against USCG drift buoy data was promising, and the models helped us to concentrate our search efforts. We thought it prudent to use multiple independent models for guidance. Each of the teams was using state-of-the-art research systems, and the systems we were modeling were inherently chaotic. See **Search, Figures 1-4** in the color insert of these proceedings for examples of the imaging and drift analyses.

7. Media

Throughout the amateur search, there was tremendous interest from traditional media and from the blogosphere in what we were doing. Very early, we decided to identify a small number of spokespeople to handle those inquiries. We had two goals: We wanted to keep the story visible, so that anyone who might spot the boat would know about Jim's disappearance, and we wanted to insulate the various teams working on the search from distraction by reporters.

8. Suspending the Search

From January 29th until February 16th, we collected and analyzed data, postered marinas, walked the coastline and flew search missions looking for Tenacious or Jim, or for wreckage that could tell us what happened to him. We found nothing.

As time passed, it became clear that we were simply running out of places to look. See **Search Area Boundaries and Image Footprint Extents** in the color insert for the extent of the search.

In the final days, we sat down with the Coast Guard to review their efforts and ours in detail. Deeply disappointed, but convinced that our efforts were unlikely to turn up new evidence, we suspended the amateur search on February 16th, 2007.

A subsequent search of the ocean floor for Tenacious failed to find the boat. As of this writing, Jim remains a missing person.

The complete absence of physical evidence has led to some speculation in the popular press. Did Jim plan his own disappearance? Was there some kind of foul play?

Those who know Jim best believe that the simplest explanation is the right one: The ocean is enormous. Even experienced sailors are subject to freak accidents. If Tenacious struck a submerged object and holed its hull, it could have sunk too quickly to send a distress signal. If it did not break up on the surface, it would have carried any debris down with it, leaving no evidence of an accident on the surface.

9. Acknowledgements

The amateur search was a remarkable blend of social networks, computer technology and science.

On behalf of all involved, I want to convey our admiration and our regards to Donna Carnes and the rest of Jim's family. In addition, we are deeply indebted to the US Coast Guard, and especially to Captain David Swatland and Commander Jonathan Copley, for their cooperation and professionalism.

The amateur search team eventually included thousands of people. We are grateful to all of them. We are especially indebted to Antonio Baptista, Tom Barclay, James Bellingham, Bob Bilger, Igor Carron, Charlie Catlett, Yi Chao, David Chiu, James Frew, Phil Garrett, Paula Hawthorn, Joe Hellerstein, Tina Hsieh, John Kindle, Ed Lazowska, Richard Mogford, Stuart Ozer, Alex Szalay, David Tennenhouse, Werner Vogels, Gordon Wells and Dick Williams for their considerable contributions. In addition, we appreciate the support of Amazon.com, Argonne National Laboratory, DigitalGlobe, Google, Johns Hopkins University, Microsoft, the Monterey Bay Aquarium Research Institute, NASA (including especially the Ames Research Center and the Jet Propulsion Laboratory), the Naval Research Laboratory, Oracle, the Oregon Health and Science University, the San Diego Supercomputer Center, Texas A&M University, the University of California, the University of Texas and the University of Washington.

Most importantly, we extend our heartfelt thanks to Jim Gray for being the kind of guy thousands of people would go looking for. We miss you.

10. References

[Fossett] http://en.wikipedia.org/wiki/Steve_Fossett

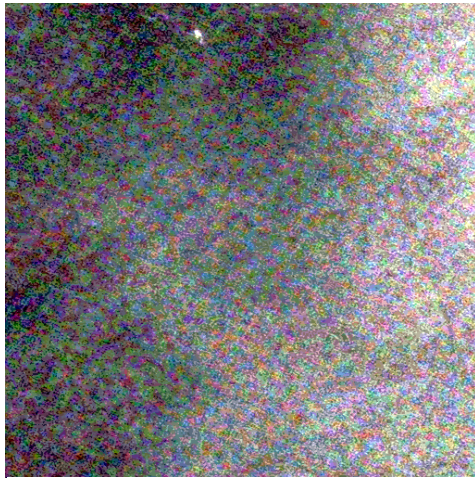
[Hafner 2007] Katie Hafner, *Silicon Valley's High-Tech Hunt for Colleague*, **New York Times**, February 3, 2007.

[Kim] http://en.wikipedia.org/wiki/James_Kim

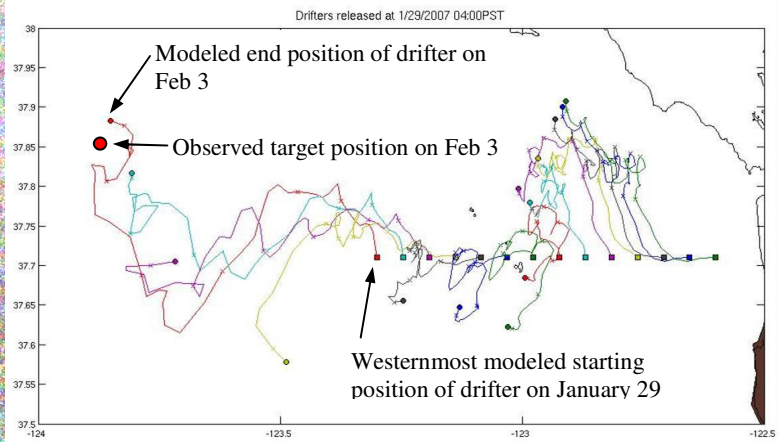
[Silberman 2007] Steve Silberman, *Inside the High-Tech Hunt for a Missing Silicon Valley Legend*, **Wired Magazine**, issue 15.08, August 2007.

[Tenacious] <http://www.openphi.net/tenacious/>

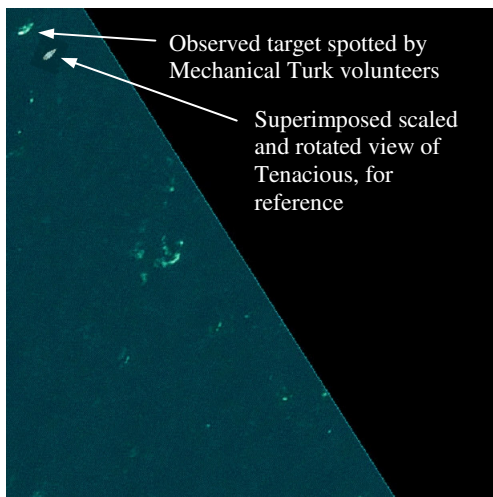
The Amateur Search: Selected Drift Analysis and Imaging Results



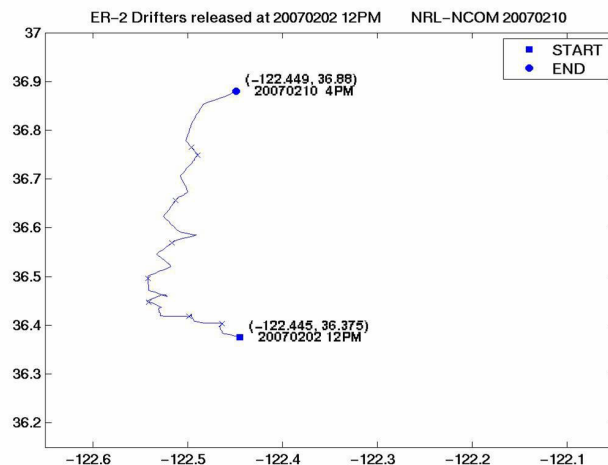
Search, Figure 1: On February 3, the Digital Globe satellite captured this image, through heavy cloud cover, showing a target near the top of the center of the picture. The target's size and shape were consistent with Tenacious. Analysis by the drift team suggested that this could be Tenacious (see Figure 2). We dispatched a search flight, but failed to find anything. It is possible that this is another boat underway and in no distress.



Search, Figure 2: If Tenacious began drifting west of the Farallon Islands on January 29, then the location of the February 3 Digital Globe target was consistent with one of our drift models. This model output shows trajectories for a number of hypothetical starting points on January 29 at 4am local time, and their ending locations under the model on February 3. The westernmost starting point produces a reasonable match for the target's location. The search team subsequently discounted the hypothesis that the boat was adrift west of the Farallons based on further analysis and interviews with researchers on the islands.

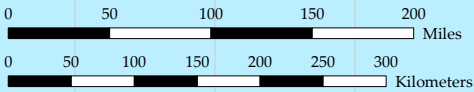
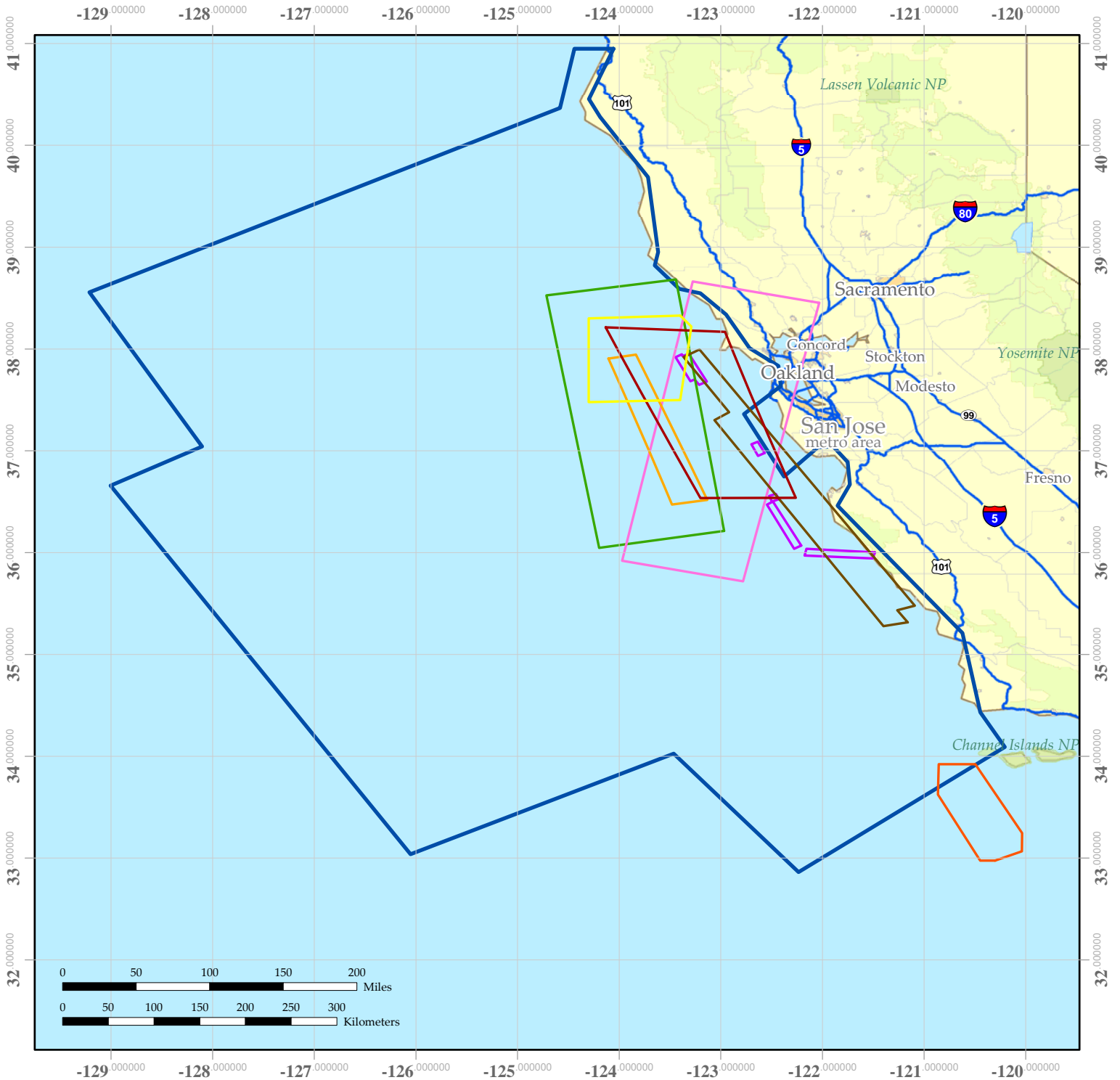


Search, Figure 3: Volunteers working with the Amazon Mechanical Turk spotted a possible target in an image shot from a NASA ER-2 aircraft overflight off the coast of Monterey on February 2. The black portion of the image is outside the edge of the picture, once the image was rotated and registered to its latitude and longitude on a map. The shape could be breaking waves, but resembled Tenacious enough to warrant investigation.



Search, Figure 4: The image processing and filtering of the MTurk target shown in Figure 3 were followed by several days of bad weather, during which it was not safe to put a plane in the air. By the time the weather cleared sufficiently to fly a search mission, more than a week had passed. We needed an updated location for the possible target. The drift modeling team produced a plot showing its likely latitude and longitude on the morning of the day we flew. As was true for our other search missions, we found no evidence of the ship and no debris.

Search Area Boundaries and Imagery Footprint Extents



February 13, 2007



United States Coast Guard
U.S. Department of Homeland Security

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Texas Advanced Computing Center
The University of Texas at Austin



- USCG Search Boundary - 2/1/2007
- NASA ER2 - 2/2/2007
- RADARSAT - 1/31/2007
- RADARSAT - 2/3/2007
- QuickBird - 2/1/2007
- QuickBird - 2/2/2007
- QuickBird - 2/3/2007
- IKONOS - 2/2/2007
- Private search (aircraft) - 2/11/2007