Overwhelmed by Technology:

How did user interface failures on board the USS *Vincennes* lead to 290 dead?

Luke Swartz

Background

On July 3, 1988, the 290 passengers and crew of Iran Air Flight 655 were seemingly distant from the bitter and prolonged Iran-Iraq war. Many of the passengers were ultimately bound for Mecca, making their sacred pilgrimage as prescribed in the Koran. However, at 10:24 AM, seven minutes after the Airbus took off from Bandar Abbas Airport for Dubai in the United Arab Emirates, the United States Navy guided missile cruiser *Vincennes* fired two missiles at the plane, destroying the hapless target and its civilian occupants with horrific precision.

What Went Wrong?

Immediately after the tragedy, the US quickly blamed Iran for letting the plane fly over the combat situation below; then-Vice President Bush explained to the UN Security Council that the *Vincennes* “acted in self-defense,” thinking that Flight 655, after failing to respond to seven warnings, was “an Iranian military aircraft…approaching with hostile intentions.” Iran’s foreign minister charged the US with intentionally downing the plane, adding, “This was a premeditated act of aggression against the integrity of Tehran…a massacre.”

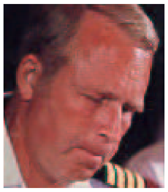
While few objective observers think that the *Vincennes*’ action was intentional, and fewer still believe that its shooting down the civilian airliner was correct, numerous experts have debated what went wrong that fateful day. Many theories deal with aspects of the situation and the key players both on the *Vincennes* and in the cockpit of Flight 655.

Failure to Respond?

We may never know why Flight 655 failed to respond to the *Vincennes*’ repeated warnings, as its “black box” flight recorder could not be recovered. Perhaps the pilots failed to monitor the *Vincennes*’ distress frequency, or perhaps they heard the challenge but ignored it, or thought it was directed at another craft. The International Civil Aviation Organization (ICAO)’s report on the accident does note that, “military units should be equipped to monitor [civilian] frequencies” in addition to the emergency frequency 121.5 MHz “to enable them to identify radar contacts.” Indeed, the pilots did stay in radio contact with Bandar Abbas Airport over such frequencies throughout their short flight. If the *Vincennes* was able to monitor civilian radio channels, the tragedy might have been averted.

Over-Agression?

Some, such as Captain Robert Hattan, the commanding officer of the nearby frigate *Sides*, charge that *Vincennes*’ Captain Will Rogers was overly aggressive the morning of July 3rd, which created the unfavorable situation that led to the tragedy. This theory was described in great depth by a *Newsweek* article entitled "Sea of Lies" and a related ABC News "Nightline" episode in 1992, which examined Rogers' engaging Iranian gunboats just before the accident. Rogers' ship had been nicknamed "Robocruiser" for its swashbuckler attitude, which was evidenced that morning as it aggressively opened fire on gunboats that had allegedly fired at or near the *Vincennes*' helicopter. By creating such a charged and confusing atmosphere, some argue, Rogers made it much more difficult to accurately determine whether Flight 655 posed a genuine risk to the *Vincennes* or not.



Commander Glenn Brindel, chastised commanding officer of the USS *Stark*, and his ship, listing heavily after being hit by an Exocet missile

However, as Admiral Vern Clark, the then-Commander of the Joint Chiefs of Staff explained in Congress shortly after the article appeared, "the U.S. rules of engagement, neglected by *ABC-Newsweek*, strongly emphasized that each commanding officer's first responsibility was to the safety of his ship and crew. If he was to err, it was to be on the side of protecting his people….ships' captains are expected to make forehanded judgments, and if they genuinely believe they are under threat, to act aggressively." Indeed, the Navy had just recently ended the career of Commander Glenn Brindel of the *Stark*, charging that he had not adequately defended his ship against an incoming missile. Admiral William M. Fogarty, head of the team investigating the *Vincennes* incident, justified Rogers' action, testifying before the Senate Armed Services Committee that not only was "the commanding officer [of the *Stark*] criticized for not taking timely action" but that Iran had recently "intentionally and maliciously planted mines which severely damaged the *Bridgeton* and the *Samuel B. Roberts*." In such a charged atmosphere, one can perhaps understand the *Vincennes*' aggression. While one might still charge that Rogers' initial engagement of the gunboats was somewhat reckless, it seems clear that his decision to fire on the incoming plane was justifiably to ensure the safety of his crew, ship, and, ultimately, career.

Misinformation, Confusion, and Aegis

One thing is certain: Captain Rogers was given bad information about the radar contact that would prove to be Flight 655. All of his decisions were made in the Combat Information Center (CIC), a dark room in which all information from the ships' various sensors is collected; he had to rely on this data to make his fatal choice. Not only was he told that the craft was descending (and not ascending, as it actually was) but he was also told that the craft's Identification, Friend or Foe (or IFF) reading, designed to distinguish between civilian and military craft, was Mode II (military) and not Mode III (civilian, as it actually was).

The *Vincennes*' CIC (Combat Information Center). Note the three large 42 x 42" displays and the smaller 12" displays below

To understand why Rogers was presented with incorrect altitude and IFF readings requires a brief familiarity with the Aegis Combat System. Aegis, the shield of Athena in Greek mythology, was the name given to the Navy's top-notch all-encompassing combat system, installed in all *Ticonderoga*-class cruisers, such as the *Vincennes*. It was designed, as was most of the 1980s Navy, for a massive "blue" (or open) water battle with the Soviet Navy; as such, it can track hundreds of missiles and airplanes for a number of ships. However, this enormous tracking power brings with it enormous complexity.

Altitude

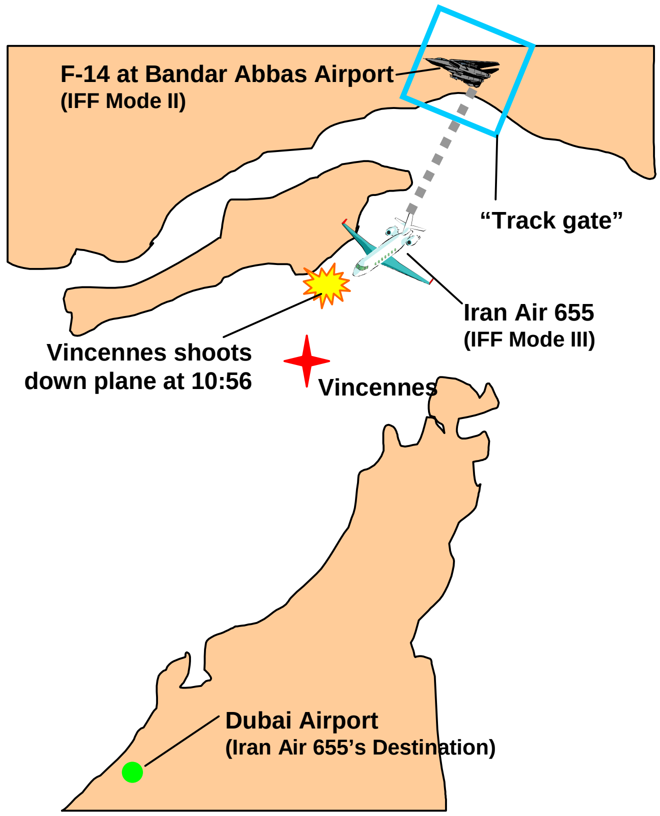
One engineer, Matt Jaffe, when he worked on the Aegis combat display system, recognized the complexity of the information it provided—specifically, the confusing way to read altitude. Eric J. Lerner, a writer for Aerospace America, notes that although three large displays show every contact, “to get speed, range, and altitude,” one must explicitly punch up that information, which is subsequently displayed on a tiny 12-inch monitor. Most importantly, this display “does not include rates of change,” forcing crewmembers to “compare data taken at different times and make the calculation in their heads, on scratch pads, or on a calculator—and all this during combat.”

Jaffe explained to his supervisor that it might be useful to add some kind of indicator for whether a craft is ascending or descending, but his superiors refused to consider the idea. They explained that first, if the Navy wanted such a reading, it would have asked for it, and second, there wasn’t enough room on the display. Sadly, had that display have been added, the *Vincennes*’ over-excited Tactical Information Officer might have seen the correct trajectory of Flight 655 and the disaster could have been averted.

That someone caught this error yet that nothing was done points to an error in the software design process—that is, the military contractor developing the display focused not on good design or on giving the Navy what it needed, but on cost and giving the Navy what it *said* it needed. Often, good software is quite different from what people say they need; for example, few computer operators in the 1970s would have asked for the graphical desktop publishing displays that are ubiquitous today. By cutting out user-interface concerns from their software design process, the military contractor indirectly caused the user-interface failure on the morning of the accident.

IFF

The second error, that of reporting an IFF Mode II (military) rather than the correct III (civilian), can likewise be explained through bad user-interface design. While the radar operator was examining the oncoming contact (Flight 655) with his trackball cursor, the IFF displayed its reading from the last "tracking gate" location. This "gate" is essentially a box that the ship's radar monitors for various signals (such as IFF); if it isn't explicitly moved, it stays in place. Thus, while the civilian Airbus plane was correctly emitting an IFF Mode III signal, the radar picked up the IFF Mode II signals from F-14's still at the Bandar Abbas Airport. Had the system been better designed so as to either facilitate moving the tracking gate, or to give a warning should one select a contact outside of the tracking gate, the disaster likewise might have been avoided.



This error, unlike the altitude error, was apparently *not* caught in design. This may be because many user-interface difficulties only manifest themselves in user testing—that is, sticking real people in front of the software to try it out. It seems that neither the contractor that designed the Aegis system nor the Navy did extensive testing of the interface, focusing more on the accuracy of the radar. Nevertheless, Chris Gray of the University of California at Santa Cruz notes that every test of the Aegis system showed numerous errors. It is unclear whether the specific IFF tracking error appeared in testing, but without a doubt user-interface testing was of little importance to the Navy.

Overconfidence

Compounding the user interface problems of failing to provide altitude ascent/descent information and having two IFF focus points, the commander and crew of the *Vincennes* put too much trust in the Aegis technology. This overconfidence spread even to other ships: the *Sides*, mentioned above, had correctly identified Flight 655 as "comair" (a commercial airliner), but failed to challenge the *Vincennes*' identification because the *Sides* lacked the *Vincennes*' "top-notch" Aegis radar. Chris Gray argues that "the Aegis gave the *Vincennes*' captain and crew the illusion that they knew more than they did"—after all, it was one thing for humans in the CIC to speculate that the contact was an F-14, but when that information was displayed on a seemingly objective computer monitor, it took on a life of its own. What those on the *Vincennes* and in the wider Navy failed to realize is that "*Aegis is a man-machine weapon system*" [italics in original]; as such, sailors must exercise a healthy skepticism about the information they are presented, rather than blindly trust the "system" of which they are unknowingly a part.

Conclusions

Where, then, does the responsibility lie? Gray notes that some want to "[turn] over…responsibility to machines." Bush blamed the Iranian gunboats and pilots. *Newsweek* held Rogers responsible for being overly aggressive. The Navy chalked the incident up to "human error" and "stress." Clearly, each of these was a factor—for example, had the Airbus monitored Navy channels or had Rodgers held back his ship from Iranian waters, 290 people may not have died.

Perhaps the strongest lesson of the tragedy is the importance of user-interface design in software products, especially for mission-critical applications such as naval vessels. Both the altitude and IFF user-interface deficiencies could have been averted had more attention been paid to design and testing of the Aegis human-machine interface. It is a travesty that this was neglected, yet can one ever catch all the user-interface errors in any piece of software? We should consider whether we should use computers at all in such high-stakes arenas. It is impossible to test a computer in all possible scenarios, and—perhaps more importantly—with all possible users. Particularly since people place more trust in information from a computer, the Navy should at least loosen its reliance on technology to make decisions. Flight 655's tragic demise might teach us not only the importance of user-interface design, but also the need to question technology in mission-critical applications.

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