

The Origins of Collaborative Decision-making (CDM)

by Norm Fujisaki

CDM has become a significant part of Air Traffic Management and more specifically Air Traffic Flow Management, not just in the US, but globally. CDM and collaborative ATM in fact are substantial components of the foundation for NextGen and Single European Sky. As a result, I was approached to recount the origin and early work that led to CDM, both from the perspective of historical interest as well as lessons for the future.

In the period from 1987-1989, T. Allan McArtor was the FAA Administrator. While many people remember McArtor as a former pilot and member of the Air Force's Thunderbird team and more recently as the CEO of Airbus Americas, just prior to and after his term at the FAA, McArtor had served as member of the senior executive team at FedEx.

Many people in the field of operations research (OR) know that FedEx was founded by Fred Smith. As a student at Yale studying economics in the early 1960s, Fred Smith wrote a business plan for an overnight mail delivery service for time-sensitive items using a fleet of aircraft operating in a hub and spoke network. He reportedly received a harsh critique and a mediocre grade on that project, but was convinced that the idea had promise. After graduating from Yale with a degree in economics in 1966, Smith entered the Marine Corps and served as an officer in Vietnam. After completing his military service, in 1970 he managed to buy controlling interest in a small aircraft maintenance firm from his father-in-law. Soon he focused the company on used aircraft trading. Using his sizable inheritance from his parents and a large amount of venture capital funding, he established Federal Express as a Delaware corporation in 1971. He started operations in 1973 using a small fleet of Falcon jets serving 25 cities. The rest is history.

In its early years, FedEx encountered significant problems. As a result, it began relying on OR techniques to improve its planning and decision-making. FedEx developed quantitative origin-destination models, models of its operation, finances, human resources, equipment, and route system. Fred Smith came to rely heavily on his OR staff to plan and run the business. As a result, OR is huge at FedEx. So, when Allan McArtor came to the FAA, he asked to visit the FAA's OR department. Of course there was none. So, he directed that one be established. There were few analysts with training in OR and even fewer executives. So, the few that did were sent to the FAA's new OR organization. Although working in policy and major systems acquisition, Steve Zaidman and I were FAA senior executives who had done grad work in OR. Dave Winer managed a group of modeling and simulation experts in the Office of Energy and Environment (AEE). We helped form the nucleus of the original OR group at the FAA.

In the first few years of its existence, the FAA's OR group worked on a number of quantitative tools and capabilities. These were foundational in nature. Working with the MITRE Corporation, FAA's Federally Funded Research and Development Center, the OR group developed the National Airspace System Performance Analysis Capability (NASPAC), which simulated 58 of the largest airports and all of the flights in the US,

including over 700 en route airspace sectors. For the first time, the FAA was able to study the effectiveness of technological improvements on a nationwide basis. It could examine the rippling effect of delay propagation from its origin in an early part of the day throughout the rest of the day and throughout the rest of the system. The OR group funded the development of the Integration and Interaction Laboratory (I-Lab) at MITRE, a highly re-configurable and flexible simulation facility to study emerging operational concepts. Ken Geisinger of the OR group with support from consultant Arnie Greenland developed the Sector Design and Analysis Tool (SDAT, a tool to analyze the operational effectiveness of alternative airspace sector designs—still in operational use today). Dave Winer and his group brought vital model development skills and capabilities. He also brought several AEE legacy projects, including SIMMOD (SIMulation MODEL, an airport surface and airspace simulation tool still widely in use today) and DOTS (Dynamic Ocean Track System, a wind-optimized trajectory generation system for oceanic flights to save time and reduce fuel burn and emissions—also, still in use today). Dave Ford, known for many of his other FAA assignments, including as high-profile leader of the Oceanic program, led the development of DOTS in Dave Winer's group.

As the early planning and analysis tools were developed, we began showing them to people responsible for air traffic control *operations*. The head of air traffic operations in the early 1990s was Dave Hurley. Dave was a benevolent dictator. Some would argue with me on the point of his benevolence. While responsible for all air traffic control operations, Dave took particular interest in Traffic Flow Management (TFM or ATFM). When Dave saw our simulation models and analysis tools, he asked if we could make them run fast enough to use in making operational decisions during the course of the day. As a result, the FAA OR group found the people and funding to begin developing a whole new set of operational tools. We developed the High Altitude Route System (HARS), which relied on DOTS algorithms to generate domestic wind-optimized trajectories to save time and reduce fuel burn. SMARTFLO was a tool based on artificial intelligence learning algorithms to make operationally optimal decisions in the face of uncertainty by relying on the results of extensive past experiences and outcomes. There were numerous other tools that were developed. At our request, Dave Hurley agreed to allow prototypes to be developed on the floor of his Central Flow Control Facility (CFCF), which at the time was located on the 6th floor of the FAA Headquarters building at 800 Independence Avenue in Washington, DC. The CFCF was managed by Charlie Hall. By being immersed in the operational environment, the OR analysts and developers learned about critical facets of the operation that would never have been possible without living on the floor of the CFCF. Their continuous interaction with the operators of the CFCF greatly accelerated the initial development and spiral refinements of prototypes. Despite the major advances that were made, up to this point, all of the OR group's experience was confined to the FAA's operation.

In the early 1990's, the FAA like many other agencies and US companies was promoting Total Quality Management (TQM) based on the Deming method. The central idea was to focus on customers and customer needs, and to deliver excellent service by stressing continuous process improvement. The TQM push at the FAA opened whole new

fundamental debates about who our customers were. The emphasis on customer focus caused me to begin visiting the airlines to get to know their OR and operations people.

As a member of the Operations Research Society of America, I subscribed to *Operations Research*, a journal of typically scholarly, theoretical papers. During the summer of 1992, an atypical article appeared in *Operations Research* about the “craft” of operations research or doing operations research (OR) in actual practice. The article was written by Hugh Miser, a pioneer in the field who began his work in OR during World War II, working with the US Army Air Corps. Miser worked with W.J. Youden, who helped form the Eighth Air Force operations analysis group that went to the UK in September 1942. Youden was known for his contributions in the design of statistical experiments, doing his early work in chemistry and building on the foundational work of R.A. Fisher. The Eighth Air Force and the British worked to improve gunnery, artillery and bombing accuracy through the use of mathematical and statistical techniques. The British began calling it operational research, since the research typically addressed operational problems. The term became Americanized on this side of the Atlantic as “operations research.”

Miser’s paper had a profound impact on my thinking about how to do OR at the FAA. One of the things Miser said in his article was that analysts need to immerse themselves in the operation they are analyzing. They need to see it for themselves. They need to talk with the operators to more fully gain an appreciation for what is really going on, how things really work, what’s important. A myriad of critical detail – or whole dimensions -- can be missed if merely relying on someone else’s reported observations. This in fact is what we had been doing on the floor of the CFCF.

With Miser’s lesson in mind, together with the TQM emphasis on customer focus, I embarked on an experiment in October 1992. I decided to take a small group of OR analysts out to airline operations centers to see the operation from the airline customer’s perspective. I invited Charlie Hall, manager of the FAA CFCF to come along, since he knew many of the operations people at the airlines. Also, I invited Margaret Jenny of MITRE, since she had supported the OR group in a number of other projects. We made the rounds, first spending a couple of days at Northwest in Minneapolis. We met Northwest dispatchers Giles O’Keefe and Bill Leber, among others, of the Northwest Operations Center. We went on to United and spent a couple of days at their operations center in Elk Grove, Illinois. We met Chris Pear, one of United’s dispatchers. Our third stop was at American’s System Operations Center near DFW Airport, where we met Don Kneram, Roger Beatty and Joe Bertapele.

At this point, it became abundantly clear that very little information was being shared between the airlines and the FAA CFCF. The FAA CFCF made all of its decisions based on their limited understanding of what the airlines were planning on doing, which was based on the Official Airline Guide – a schedule of airline flights published every 56 days for use by travel agencies and others in addition to the FAA CFCF. The Official Airline Guide, while quite useful, is considered to be out of date when it’s published and really out of date by the end of the 56 day cycle. The airlines make various schedule changes,

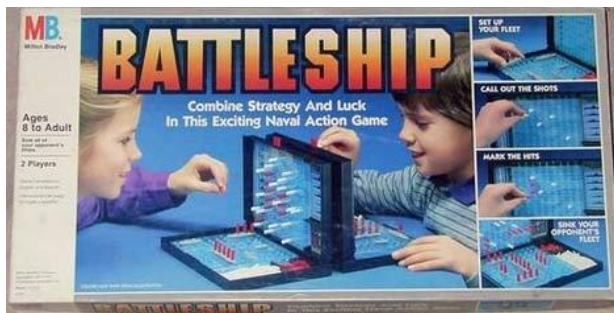
cancel flights or delay them due mechanical problems, crew problems, passenger bookings, weather conditions, and other reasons. But, they refused to share that information with the FAA. It seemed irrational until we learned that the FAA's procedures and systems, if updated with a delay or cancellation, would give the time slot away – often to a competitor – and offer no provision for re-accommodation at a later time. The airlines even had a name for the phenomenon: “double-whammy,” help your competitor and screw yourself. Previously trying to engage the FAA on this issue had not proved to be fruitful. As a result, there was a high degree of animosity and distrust.

After a substantial amount of coaxing and diplomacy, we managed to convince a number of the airlines to participate in a project that we called the FAA-Airline Data Exchange (FADE) program. Under the agreement, the airlines would stream their flight schedule changes to the FAA's OR group with the understanding that the information would not be used for operational purposes – no double-whammy. Instead, the OR group would examine how the fresh airline schedule data might be used to make better FAA decisions. Better decisions would allow the system to work more efficiently for the individual airlines as well as the overall system, the latter of which had been FAA's sole focus in the past. We agreed to a six month test period and committed to providing a report of our results. In addition to Northwest, United, and American, subsequent visits included Delta, US Airways, Continental and Southwest. So, they participated as well.

The FAA OR team working on FADE included Mark Salanski, Tom Mifflin, Timmie MacArthur with oversight guidance from Norm Fujisaki and Dave Winer. MITRE provided Mike Wambsganss and Midori Tanino to work with the OR group. Tom Mifflin soon moved to Metron, Inc. Mike Wambsganss and Midori Tanino moved to Quantech and subsequently to Metron, Inc. By mid-1993, the initial FADE results showed that there were clear opportunities to make good use of updated airline schedule information, particularly during periods of massive schedule delays caused most often by bad weather—what the airlines and FAA euphemistically refer to as “irregular operations.” As promised, the FAA OR group reported the results to the airline community. There were still lingering feelings of airline mistrust. So, the FADE team proposed a few ideas to bring about some fundamental changes to the way the future system might work. We talked about a future concept wherein FAA procedures and software functionality would *reward desired behaviors*. Sharing accurate airline schedule changes would make the system work better, so what could the FAA do to encourage the airlines to provide more timely and accurate schedule change information – how might the FAA reward that kind of desired behavior? The FADE team proposed that those airlines providing timely and accurate schedule changes might be given the opportunity to use the vacated time slot for themselves. Moving another one of their flights into a vacated time slot would in turn create another time slot, which they could then use for another one of their flights. In that way, they would benefit directly from reporting the schedule change. If unable to do so, only then would other carriers be able to use a vacated slot. The process of using a vacated slot, first by the airline that created it and then by other airlines only when the originally reporting airline could no longer use vacated slots, was called “compression.” Once the schedule was compressed, airlines could substitute among their own flights to best meet their respective business objectives. In a simplistic sense, compression and

substitutions provided a structured way to more optimally repack a schedule to make maximum use of available time and allow individual airlines to maximize attainment of their business objectives. To make it all work, airlines would have to share schedule change information in a timely way. To encourage the airlines to share the information, the FAA would have to change the rules of the road by rewarding the airline behaviors it wanted, ultimately to improve the performance of the overall system.

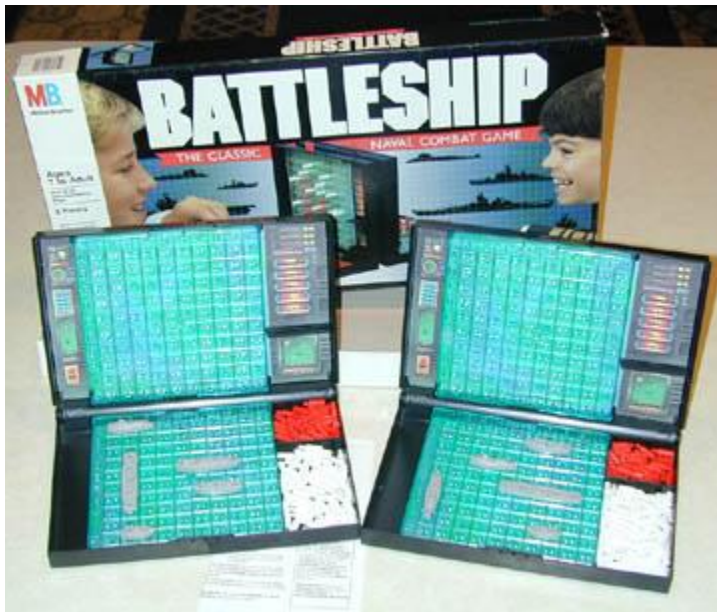
Most people who have done air traffic control and then done traffic flow management will tell you that TFM concepts are an order of magnitude more complicated. The complexity of TFM often presents challenges in getting people to agree to bring about needed change. To OR people and airline operational experts, the results of the initial FADE work were compelling. But, there were a lot of other people involved in making the decision to pursue recommendations suggested by the FADE results. There were competing ideas, programs competing for funding, personal agendas, and a general lack of understanding of the complexities being discussed in the FADE results. In an effort to deal with the complexity issue, I decided to use an analogy. I brought in my son's Battleship game. Most kids have been exposed to this Milton Bradley board game. Each player has a board that is hidden from their opponent's view. Various sizes of battleships are placed randomly on the gridded surface of the ocean. Each player then calls out grid coordinates on their opponent's hidden grid. Depending on whether a ship is occupying the called grid coordinate, the owner declares "hit" or "miss." The players take turns with the objective of sinking all of their opponent's ships first.



To accentuate that which was being proposed by the initial FADE results, I suggested that the current TFM system of that time was a lot like playing Battleship. The FAA couldn't see what the airlines were doing and the airlines couldn't see what the FAA was up to. They lobbed shots in an effort to manage their own problem, often hitting each other's "ships" in the process.

The proposal was to change the rules of the game entirely. The playing boards would be turned, so that each player could see the other's grid. Instead of having stationary ships, they would become moveable. When shots were fired, the object would be to try to miss the other's ships. Finally, before each player's turn, they would declare their intentions and provide the other with an opportunity to provide feedback prior to taking action. The objective would be to fill up the grid without hitting any ships. Analogies sometime work

and sometimes don't, but on this occasion, it seemed to work well. The OR group was given the green light to proceed to the next stage of development, which was to build prototype compression and substitution tools.



Over the course of the next 12 months, the prototype Flight Schedule Monitor (FSM) was developed to reliably perform schedule compressions and support airline substitutions. Processes and procedures were developed to support the overall concept. Much of the prototyping continued to be done with the close involvement of both FAA and airline operational experts. As a way of testing the effectiveness of these new tools, a full scale human-in-the-loop simulation was planned. The FADE war games were held at Metron, Inc. located in Reston, VA, on December 6-7, 1994. Thirteen individual airlines came to the war games. Each airline had its own cubical representing their individual operations center. Each brought along notebook computers with their custom software tools used at their own operations centers. I recall they were quite protective of their laptop screens as their competitors walked past the opening of their cubical. The FAA's old, cramped CFCF on the 6th floor of the Headquarters building had been replaced in the spring of 1994 by a spacious, modern facility, the Air Traffic Control System Command Center (ATCSCC), located in Herndon, VA. In the war games, the ATCSCC was housed in Metron's library.

Charlie Hall, who had served as the manager of the old FAA CFCF for several years and for several months at the new ATCSCC, suddenly developed medical problems and retired in the fall of 1994. He was succeeded by Jack Kies, who was hand-picked by Dave Hurley after spending most of his FAA career at the NY TRACON and FAA Eastern Region Air Traffic Division. After having relied on our very close relationship with Charlie Hall, I had concerns about having to start all over building a new relationship with Jack. I can still recall Charlie Hall telling me that if I ever needed anything from the ATCSCC, just call Jack; he said Jack would be very supportive of the kinds of things we were trying to do.

As the FADE war games were getting organized for a full two days of intensive work, some of the FAA operations people began complaining about the way the war games had been structured. These in fact were individuals who had alternative agendas and had been unhappy about the support FADE had been getting. To a degree, FADE had diluted the financial and political support that their program had been receiving previously. With thirteen airlines listening to a few official sounding FAA managers throwing rocks at FADE, the war games were in jeopardy. Recalling what Charlie Hall had said, I called Jack Kies. At this point, I had neither met Jack nor ever communicated with him. Fortunately, I was able to reach him. I explained what was going on and asked if he might be available to come to Reston to straighten out the mess. Much to my pleasant surprise, he said he would be right over. Jack arrived in about 20 minutes and a few minutes later everything calmed down. I think it was a combination of Jack's imposing physique and his New York manner that got the detractors to quickly back down. It didn't hurt either that Jack had a direct line into Dave Hurley, who was supportive of FADE as well. This was the first time I met Jack Kies. He was forward-thinking, open to change, and always wanted to do the right thing, even if less convenient or harder on himself and his organization. We researchers were back in business.

The FADE war games called for a number of scenarios where weather or traffic volume were forecast to reduce the amount of flights that could be accommodated in a specific terminal area during a busy part of the day. Real traffic and weather were used for each of the scenarios. So, we had real world results based on how the real world system ran with the use of existing concepts and tools and, through the war games, a set of simulated results using new concepts and tools with the same real world traffic and weather conditions. Who could ask for a better basis for comparison? There was a scenario for San Francisco fog and New York volume. The most memorable scenario for me was the one involving snow at Chicago. That day in Chicago, there was heavy snow falling. American and United are dominant carriers in Chicago and they were being hammered. Using new concepts and tools in the simulation, however, over 75 percent of the delays were averted. On average delays were reduced for all scenarios by 35 percent. Aside from the impressive improvements enabled through compression and substitution, the Chicago scenario proved to be particularly interesting because of the contrast in operating styles exhibited by American and United. American had been known, and still is, as the conservative, orderly, disciplined airline. When conditions are forecast to get bad, American immediately begins positioning for an orderly contraction and for an efficient start-up when conditions return to normal, typically the next day. United had been known as the cowboys, always pushing hard to get as many flights as far as they could, fighting to get as many passengers to their destinations. As a result, they had many more diversions. Their aircraft and crews were in a bit of disarray, preventing an orderly return to normal operations. Sometimes it took days for United to recover. Following the war games, it was fascinating to hear American saying that perhaps they ought to be a little more like United and take a few more risks, while United was looking at American's performance and saying to themselves that perhaps they should be less aggressive and more proactive.

The December 1994 FADE war games represented a major milestone for Traffic Flow Management. It provided irrefutable proof that information sharing was invaluable to dramatically improving the performance of the system. Through compression, substitutions and greater collaboration, not only would the performance of the system improve, but business performance of the individual airlines could be enhanced and the vital sharing of schedule change information itself could be ensured by rewarding desired airline behaviors through these new concepts and tools.

The FADE war games also represented a major milestone in the sense that FADE would be transitioned from the OR group to an acquisition organization for broader, longer term operational implementation. At the conclusion of the FADE war games, the responsibility for the project was handed over to Jim Wetherly of the Air Traffic Management Automation acquisition group. Jim would work with Mark Salanski, Timmie MacArthur, Steve Alvania, Barry Gamblin, Mike Wambsganss, Midori Tanino and others to give the concept its current name, Collaborative Decision-making (CDM), and take it to new heights.