Moving from Complicated to Complex: An Organizational Transformation

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My Organization was the Crisis

I am a retired system engineer and as I look back on my career, I am struck by a radical change that occurred in the division where I worked at the MITRE Corporation. This story focuses on specific events that led to the major organizational changes in the

Center for Advanced Aviation System Development (CAASD) at MITRE. An accompanying piece on The Alaska Capstone project goes into greater detail about specific organizational changes that occurred in conjunction with modernizing the Air Traffic Control (ATC) system.

MITRE is primarily a system engineering company, headquartered in McLean Virginia and Bedford, Massachusetts, close to its key customer, the Federal Government. It has a highly trained staff of mostly engineers, along with human resource specialists, computer scientists, and specialized technical support people. It operates as a Federally Funded Research and Development Corporation (FFRDC)* and provides technical advice and research focused on the use of technology for different government departments (the Department of Defense, the Federal Aviation Administration and Health and Human Services).

I worked in the Center for Advanced Aviation System Development (CAASD) and the agency we serviced was the Federal Aviation Administration (FAA). Our primary job was to perform research and recommend how the agency should continue to modernize the Air Traffic Control (ATC) system. Our division had been instrumental in designing the first automated ATC system in the United States, which became the standard in the 1960s for the world. In the 1980s the second major ATC modernization program (labeled the Advanced Automation System), costing several billion dollars, failed, resulting in a cancellation of the modernization initiative. The reasons for this failure are spelled out in attachment 1. The initial response of the project team at CAASD was consistent with that of other highly technical organizations: “We are really the smart people and those idiots just don’t understand what they need to do.” At the time, we did not actively express our concerns about the progress of the implementation and did not seriously present any of our immediate concerns beyond the program office. In retrospect, we did not even see some of the potential problems as they were emerging.

MITRE, and thus CAASD, is a non-profit Federally Funded Research and Development Corporation (FFRDC). Its responsibility is not to shareholders

but to Congress and the American people. It is expected to provide independent assessments regardless of our immediate sponsor’s positions. We failed to uphold the responsibility of oversight and assessment and that was the genesis of the crisis of MITRE/CAASD. Congress concluded that money shouldn’t be spend on MITRE/CAASD since we had been so ineffective. Congress was ready to zero out our funding. This was the existential crisis for the division. Fortunately for the CAASD, there was a new assistant administration for acquisition at the FAA in the early 1990s and he believed

and valued the role of MITRE/CAASD, and promised Congress he would make it effective.

Federally funded research and development centers* (*FFRDCs***) *are public-private partnerships that conduct research for the United States Government. They are administered in accordance with U.S. Code of Federal Regulations, Title 48, Part 35, Section 35.017 by universities and corporations. There are currently 42 recognized FFRDCs that are sponsored by the U.S. government.[1] FFRDCs are similar to the University Affiliated Research Centers run by the United States Department of Defense. https://en.wikipedia.org/wiki/United_States_Department_of_Defense*

Appreciating the Difference - Is this Complicated or Complex?

Transforming an organizational structure and culture to address challenges and opportunities that are complex, not complicated, was not a criteria for the existing managerial mindset. Understanding and recognizing the differences between a complicated problem and a complex problem directly influences how decisions are made and actions are taken. All systems can be generally categorized as simple, complicated, and complex and short definitions are found in the Plexus key terms and vocabulary resource.

The late Brenda Zimmerman (1) provided an example of "simple, complicated, and complex" systems that is both brutally simplified here and perfectly understandable.

- Simple system: following a recipe to bake a cake;
- Complicated system: following a blueprint to build a rocket, then launching it;
- Complex system: raising a child.

This story helps illustrate how the specific changes in the organization evolved through time, what impact these incremental changes had on the

organization, and how the goal of modernizing the ATC system serves as a lens to view principles of complexity management. My reflections on the story, as *an active participant* during the original events and *in retrospect* from a complexity perspective, will hopefully offer insights that prove helpful to others who deal with complex systems.

Responding to the Crisis

How was it possible for 15 people in CAASD to rethink how the FAA should modernize the ATC system and convince management and the entire aviation community to adopt their approach? What gave this team the courage and desire to take risks and achieve so much so quickly? The story is a brief retrospective on what happened. There are several attachments that explore in a bit more detail some of the points made in the subsections.

In our corner, we had a remarkable leader, Jack Fearnsides. He knew engineering but also had a political background, honed during his time as a high-level official at the Department of Transportation prior to joining MITRE. The first thing he did after our near demise was not to blame Congress or the FAA, but to look internally. He concluded that we had indeed failed the FAA and Congress and that our narrow and arrogant perspective was one major cause of this failure.

He first identified and then surfaced our myopic view of only considering the engineering aspects of a problem. He concluded we needed fuller understanding of the needs of all the participants in the system: pilots, controllers, airlines, passengers, congressional leaders, aircraft manufacturers, and airport managers (referred to collectively as partners/stakeholders).

Why didn't we seek ongoing feedback from everyone? Why didn't we have the courage to speak out forcefully when we had concerns that the modernization project was failing? Why didn't we take responsibility for success beyond the technical recommendations?

Jack understood the need for a deep introspective look at how we conducted business, which led to a realization that fundamental changes were needed at a systemic level--for the organization, the people, and how work products and deliverables were viewed. These changes were driven by a fundamentally new awareness and recognition that would drive our mission: [4]

Even though we did not have the expertise to address all aspects of what was needed to implement the modernization of the ATC system, we had to look at the problems holistically and had to make sure that issues associated with the whole system were being addressed and not just the technical ones.

You might ask, isn't that the FAA's responsibility? The answer is yes, but given

MITRE's role and our responsibility to Congress, we were chartered to share in the responsibility, although it was not clearly articulated or understood by everyone including the FAA.

Two important changes occurred that shifted operations and strategic decision making. This first was adopting and integrating the practice of outcome management. Outcome management changed how the project was designed and subsequently managed by starting with the outcomes we wanted to achieve. We could no longer be passive observers in defining and implementing the outcome. For example, an outcome would be a cost effective change in the system that provided benefits to all the participants. Changes could be measured and achieved within a specific timeframe and were adaptable so as we learned more, the outcomes could be adjusted. We realized that for an outcome to be evaluated and implemented (1) the partners/stakeholders would have to be involved and (2) diverse types of expertise would have to be brought into the ongoing analysis, design and implementation process.

As we recognized and accepted that technology answers alone would not yield the desired outcome, we developed a fundamental shift in thinking that profoundly changed our division and our behaviors. We had to change how we operated and what people and skills we needed to bring to the table. We had to hire and develop staff that could identify and work with other organizations. We needed to seek individuals who were good engineers but also staff with good communication and interpersonal skills and knowledge of operations, economics, and politics. Before the crisis we worked solely for the implementation divisions within the FAA. Afterwards, we expanded the scope of work to the safety divisions and the operations divisions. This enabled us to develop and expand our understanding of the issues facing the entire system.

Another formal organizational change that was instituted during this time was the establishment of a new role called outcome leader. This position now reported to a different division director than the project managers, and all outcome leaders had the responsibility to have active oversight of all aspects of modernizing the ATC system within their area of responsibility. This was

distinguished from the project managers' role that was mostly focused on producing products, staying within budget, hiring the right people, and managing.

The second fundamental change in how the organization operated was the emergence of a learning culture that emphasized continuous assessment of individual and group capacity to evaluate and achieve incremental milestones in the project--we were learning as we worked. We moved from a rigid top-down structure to one that was

devolved. It is important to distinguish between the operational structure and the formal structure. Although we still had a center director, several division directors, many department managers and outcome leaders, operationally we behaved more like a network organization. (More detail is provided in a companion story on the Alaska Capstone project.)

I use the term “devolved” to mean that division and project management gave and shared more responsibility for developing relationships and making decisions with partners and staff. The pairing of outside participants to staff was often based on the needs of the project rather than the matching of role or rank. The direct benefit to this pairing of outside participants to staff resulted in all of us understanding the problems and issues better because we had far more input than if only a few people had the responsibility to meet with a few selected stakeholders. Also, this sometimes led staff to self-nominate for important roles. By self-nomination I mean that staff actually identified areas that needed addressing; they would recommend these areas to management; and they would often ask to fill them.

The evolution of leadership was influenced by the newly created position and authority of the outcome leader, whose expanded responsibilities encompassed a long-range, system-wide overview. Outcome leaders worked with division and departmental leaders and project managers to reach specific measurable organizational achievements.

The synergy and tensions inherent in these positions and their ongoing interactions offer insight into the broader dynamics of how the organizational changes created immediate opportunities and challenges. A perfect example arose during my tenure as outcome leader for FAA communications oriented projects. The FAA had selected a relatively new technology for its next generation radio, which was a major component of the ATC modernization. It was an advanced technical solution but in my assessment, along with that of many of the partners/stakeholders, there were serious drawbacks. Specifically it would require that all aircraft be equipped with two separate radios (one for for international communications and one for US) and a

revamped ground infrastructure across the US. Many members of the international and domestic aviation community agreed. This technology, although promising, was not likely to be quickly adopted internationally, in large part due to economic structure of development and implementation.

The CAASD project manager was motivated to endorse the FAA selection of a new radio solution. Based on my continued reservations, I commissioned studies and analyses that addressed perceived shortfalls, and made sure that the FAA management and the stakeholders/partners received the studies. The CAASD project manager continued to provide

different studies that the FAA demanded to keep the development process moving forward. This difference in approach created a new level of tension between me and the CAASD project manager, but we maintained a viable working relationship. The FAA project manager respected me as an outside critic, although not always happily, and accepted the supplemental studies that I commissioned. Ultimately, the FAA adopted a technology that was more in line with international standards and with what the airline industry and other partners wanted. I believe our efforts to provide alternative analysis guided the FAA to more closely align, coordinate and adopt a technology consistent with international standards and expectations of the airline industry and other partners.

The incremental changes in the operating culture supported continuous learning and created an environment that enabled teams to take more risks through calculated experiments, evaluate emerging outcomes, and quickly make changes as circumstances changed.

Table 1 (below) highlights the fundamental shifts from the Old to the New CAASD Organizational Structure.

Table 1: Old and New CAASD Characteristic Old CAASD Division New CAASD Division Scope and Focus

Technical aspects of the ATC system

All components of the modernization of the ATC system required for successful implementation

Personnel Primarily engineers Primarily engineers plus economists, ex-pilots, ex-controllers, operations research people, and human factors people Partners/ Clients

The FAA The FAA, plus industry associations, Congress, aircraft manufacturers, airlines, airports,

avionics manufacturers, air traffic controllers and unions, and general aviation Interaction with Partners/ Clients

Interactions limited to CAASD middle and high level management

Dramatic increase in direct engagements by staff with partners Product Reviews

Almost all briefings, communications and products had to be reviewed by middle and senior management

All significant products are now reviewed by middle and senior management but many briefings and communications have limited review and responsibility for these are at the staff level Management Structure

Division leaders, department leaders, group leaders and staff, reporting up a chain of command

Introduction of outcome leaders who worked with division and department leaders to achieve an outcome Staff Opportunities and Growth

Staff stayed within their specified specialty with ATC (communications, navigation, automation, etc.)

Increased opportunity for staff to move across specialties with the intent of providing new perspectives to these different areas. Assessment of Success

Success was generally defined as our positive or negative relationship with our sponsor.

Success included both feedback from the client as well as our ability to achieve positive outcomes.

A Critical Moment in Our Organization and the FAA: Courage to Trust Staff and ‘Do the Right Thing’

One of the most critical moments in our organization’s history illustrates the shifts associated with the new CAASD, specifically the increased involvement of partners and stakeholders,

trusting staff and giving them more responsibility, taking appropriate risks and looking at the problems from a holistic approach. One of the more important distinctions when managing in a complex adaptive system (CAS) and working with interdependent components of a project is creating the conditions to make decisions that recognize that short-term benefits may not be the best decisions in the long term.

What happened next set in motion the “differences that made a difference.” In 1998 the new administrator of the FAA, Jane Garvey, met with the

president of my division of MITRE, Jack Fearnsides. She had deep concerns that the leadership she had inherited had not learned the lessons of the past failures to modernize the ATC system. She wanted a fresh look at the problem of modernizing the ATC system and more stakeholder involvement. Because MITRE/CAASD was an FFRDC, she felt that our charter was in the public interest and that we should be more involved in understanding the industries’ concerns and more active in setting the direction for modernizing the ATC system.

Jack Fearnsides was clear that the approach of the modernization program had to change from the current FAA preference. He was faced with an enormous professional challenge. He knew that if he proposed something radically different from the plans of the key leaders at the FAA, he would have enemies for life.

He had a choice of being straightforward with the changes he felt were necessary, or he could acquiesce with the current FAA approach. If he acquiesced with their current approach, he would satisfy the FAA bureaucracy but only partially satisfy the administrator. If he was direct about the changes required he would probably satisfy the administrator and the aviation community but not the FAA leadership. One decision was relatively safe, but would not have stimulated the changes that were needed to modernize the ATC system. The latter was risky for both CAASD and Jack, but had the chance for real positive change.

After much agonizing, he decided to be bold. Jack asked me to assemble a team of “change leaders within MITRE” to come up with recommendations that would offer industry and FAA leaders a new approach to modernizing the ATC system. He wanted the ideas to spring from the MITRE people most involved in ATC modernization. In the past (1) CAASD would have acquiesced and would not have challenged FAA’s ideas, and (2) the division management would have done most of the work.

At the first meeting of these change leaders, I expressed that this could be viewed as a risky enterprise and that if we failed, we could all be out of a job. Of the 15 people who assembled, all committed to the project. We met for 10 days with minimal involvement of Jack or upper management. At the end of these 10 days, we presented our work to Jack and his key managers. Feedback from Jack led to the next level of modifications, which

were then pre-briefed with leaders at the FAA and the industry participants. The pre-brief involving industry was another example of how our engagements changed.

The feedback from the FAA and industry participants led to another revision, which was then presented at a two-day meeting with key leaders from the airlines, airline manufacturers, FAA, and general aviation. We presented an incremental approach to modernization instead of changing the entire system with one or two large projects. System improvements would be prototyped and then installed as controlled tests in a few field sites; if the improvements worked, they would be implemented nationally. The participants came to a consensus about this new approach. After this meeting the administrator approved the approach and asked RTCA (an industry-FAA forum for addressing standards and policy issues) to flesh out the details.

This new ATC modernization approach, which relied on learning and continuous feedback, led to the most successful implementation of new improvements in over 30 years and was adopted within the FAA. The Capstone Project, which will be discussed in a subsequent story, was one project that was designed and followed this incremental approach.

Jack was right. His decision to move forward with substantive changes to the FAA approach did not earn him immediate friends. The new approach challenged much of the FAA's higher management and they did not respond positively. In fact, our organization suffered a cutback in funds and he was subsequently asked to leave MITRE. Several years later, after the new development and project management approach was accepted and resulted in significant improvements to the ATC system, I was at a conference and seated next to Jack. The deputy administrator of the FAA was presenting a list of all the improvements to the system and the attendees were also excited and pleased by the progress. I turned to Jack and asked him, "Doesn't it bother you that they are all lauding the accomplishments but are not singing your praises?" He said, "My satisfaction is that we all accomplished something important. Who gets the credit is not that important to me."

The Lasting Impact on the Air Traffic Control System and CAASD

I suggest that the only way to evaluate whether these changes in the organization were positive or negative is to consider the impact these changes had on the both external

and internal organization and the systems in which it operated. Was the ATC system being modernized in a way that provides benefits to the aviation community and the public? Did these

changes improve the morale and viability of the internal organization (CAASD)?

My answer is YES to both of these questions. First, an incremental approach that involved greater stakeholder involvement and iterative development was adopted and this led to significant organizational and operational changes that focused on the introduction and integration of new functional capabilities to the system. A list of these improvements is presented in attachment 2. As mentioned above, CAASD was instrumental in getting this incremental approach accepted.

With respect to the our relationship with the FAA, it improved and our contract was continually renewed for five year intervals between 2000 and 2015. FAA accepted more recommendations of CAASD, and CAASD became more sensitive to the political and internal pressures facing the FAA.

Internally, staff enjoyed the greater autonomy and gained satisfaction and a sense of accomplishment that progress was finally being made in modernizing the ATC system. Most of the management adopted the practices that are presented in Table 1 under the “New CAASD.”

The Evolution of Changes Within CAASD, MITRE and the FAA

The story up to this point seems straightforward--crisis, resolution and everyone lived happily ever after. However, in a complex adaptive system, outcomes are rarely linear. This high level overview of the organization, presented as four iterations of the CAASD organizational structure changes, are defined by changes in leadership focus.

The events that triggered the crisis occurred in 1994. The first iteration, in direct response to the crisis, occurred between 1995 and 1999 as the organization slowly adopted the organizational and operational principles described in this story. The initial changes in the organization were not wholly supported because many of the project managers saw this new “outcome” focus as nothing but a fig leaf for showing the FAA that we had really changed.

Understandably, the project managers did not want to relinquish any power or influence. However, by 1996 and 1997 the situation had begun to shift, which was primarily a result of giving the outcome leaders the power of the purse and authority over what project or program proposals would be presented to the FAA. (The FAA's process was to have CAASD propose a project or program that they would modify.) These changes were also

reinforced by the division lead and the division directors who supported the new structure. However, with the significant changes to existing and familiar ways of operating together, the relationship between CAASD and many parts of the FAA was temporally strained.

During the second iteration between 1999 and 2007, the relationship between the FAA and CAASD improved. As the CAASD became increasingly more skilled in dealing with the differences in approach and conflicts that arose from our new involvement in projects, the FAA accepted our seat at the table and we learned to make more compromises. The role of outcome leader and the operational infrastructure of the organization had matured. However, this came at the expense of some of our independence.

In the third iteration (2007-2012) the emphasis began to shift toward the growth of CAASD's organizational capacity, rather than the fulfillment of outcomes. This was driven by the fact that although Congress had line-item funding for us, different project offices could also assign additional funds to this line item. To grow significantly, we had to attract these funds. As the proportion of our funds coming from the project offices increased, our desire and ability to operate independently shrank. In 2003 the Congress established the Joint Program Development Office (JPDO), which was an experiment in having six agencies (DOD, FAA, NASA, Commerce, DHS and DOT) collaborate on the modernization of the ATC system. This led to a reversal of the incremental approach that ultimately was abandoned in 2014 when the program was terminated and the incremental approach was again adopted. CAASD during this period opposed the JPDO plans but was not very aggressive in expressing its concerns.

During this period my career took a nosedive. I along with some others developed an "underground" group called the "Boat Rockers" that did our best to maintain independence and call things out as we saw them. We were tolerated by the organization but had limited immediate impact. However, as time went on the ideas we surfaced during this period were resurrected and had major impact. I believe that our concerns helped result in the demise of the JPDO.

In the fourth iteration, from 2012 to now, the organization began slowly to return to the organizational culture established in iterations 1 and 2. A very talented leader developed strong relations with the FAA and managed to restore some of the balance we had in iteration 2. I left MITRE just after the 4th iteration came into existence so much of what I am reporting comes from my contacts with some of my “Boat Rocker” colleagues. Many of them lost their influence and positions in iteration 3 and now find themselves again in leadership positions.

This is not the end of the story. In 2017 a new president of the entire MITRE Corporation was selected. Very early in his tenure as president he reorganized the entire company into portfolio managers and project

managers. I was not there for this change so my assessment of what followed comes from accounts of people still in MITRE. The portfolio and project approach is similar to the one that we developed within CAASD, with just a difference in titles and naming of groups.

Again, the transition has not been easy. Some divisions within the organization see this as just a renaming of what they have been doing while others understand the true meaning of this change. One of the big factors influencing how different organizations respond to change comes from their funding sources. Divisions that have their funding strictly related to the desires of individual project offices have less independence than those that get their funding from the Congress or the agencies’ leaders. Consequently, the external environment continues to have direct and indirect influence on how far certain organizational changes and new systems can be implemented.

What This Story Has to Do With Complexity Ideas

This story is about how a crisis offered people in the CAASD division within MITRE an opportunity to fundamentally rethink their understanding of their mission, organizational structure, staff engagements, and interactions with other stakeholders. It offers an on the ground view of how an organization transformed itself to deal with complex problems rather than complicated problems, even without acknowledging the differences. This is a story of courage and risk taking, illuminating why many of the principles of managing within and across organizational systems have emerged from the science of complexity.

I have recently begun studying the field of complexity theory as it applies to organizations and discovered a set of applicable management principles derived from complexity science that are consistent with what we developed at CAASD.

While the development of the Air Traffic Control system was a complicated integration of technology, the problem of updating and fixing the ATC system was, in fact, complex--an example of working to solve a problem that relied on the integration of complex decision making in human systems. We had to adapt our organizational culture and approach to successfully address the considerations that went beyond implementation of a highly complicated technological solution. We had to learn how to raise a child, not follow a blueprint to build a rocket, then launch it. My takeaways come from my own experience as well as knowledge that I have gained being a member of Plexus Institute.

A brief set of takeaways may offer some new ideas and options for action when working in and with a complex adaptive system:

- Move operationally toward a collaborative management approach that is network-oriented and non-hierarchical;
- Focus on early involvement of all the partners/stakeholders;
- Encourage rapid prototyping so problems can be identified early and fixed;
- Trust decision making at many levels of the organization;
- Encourage smart risk taking, constant learning and feedback cycles;
- Articulate a clear vision of what we want to achieve in alignment with team commitment;
- Most important, continuously engage in a holistic search to understand all the factors needed to achieve a successful outcome.

There is one question that has intrigued me, and that has to do with the tension between an organization that is hierarchical where authority becomes greater as one moves up the management chain, versus one that is truly networked where there is no real hierarchy.

The companion piece on the Alaskan Capstone project provides additional detail on how CAASD managed this specific project and illustrates in more detail some of the principles mentioned above.

Personal Reflections

This story and my reflections are personal. Although it may read as if I had all the right

answers and everything worked out, this is far from how it happened. I struggled to find the balance between being combative, diplomatic or even acquiescent when I thought CAASD's or the FAA's decisions were wrong. I was sometimes referred to as the bull dog. It takes skill to know how to respond when you think something is wrong. In fighting for what one believes is right, one needs to understand the environment. When is the time right to press for change and when is it not? It took me a long time to learn this lesson and my poor judgment in this area at times hurt the outcome and didn't help my standing in the organization.

Finally, there were times when my emotional stability was shaken by the struggles and anxiety of the changes that we were going through. This impacted me personally and also clouded my judgment at times. What I have learned is that managing to deal with complex systems is not just a matter of understanding the principles of how to deal with

complex systems,
but requires a strong degree of self-awareness and the ability to live with uncertainty.

I believe we often want to have the illusion that we can control events, that we can't trust others because they may fail and take us down, and that we can avoid major risks. Our egos often lead us to think because we are in a leadership role that we need to have all the answers. I believe that to deal effectively with complexity, one has to struggle to manage these feelings and accept the true nature of complex systems. Complex systems are not controllable. Even though there are good practices to operate within complex systems, there is no certainty for how the outcomes will unfold.

So....*How was it possible for 15 people to rethink how the FAA should continue to modernize the ATC system and convince management and the entire aviation community to adopt their approach? What gave this team the courage and desire to take risks and how was so much achieved so quickly?*

My personal learning journey continues and as I learn to recognize and apply the principles of complexity in human organizations, I now have some idea of where the answer lies. I believe that it is the ability to address challenges through an Adaptive Vision--the combination of knowledge, commitment, passion and trust that that guided a group of dedicated individuals to achieve their passionately held goals.

Our team had the vision to see the modernization of the ATC system as a calling and had the skills to envision how it could be done. This quote from "Getting to Maybe," sums it up perfectly (2).

"Looking back, the social innovator has a sense that a door opened--however

briefly. At the beginning there could be no certainty that the door would open. Still, it opened. Knowing it had opened, seeing it open; having the will to move through it was made possible by intentionality, the consciousness that comes from paying attention to real-world dynamics and the vision of the possible.“

Endnotes

1) Brenda Zimmerman presentation
https://cdn2.hubspot.net/hubfs/316071/Resources/Workshop%20Presentations/CCI2010_BZimmerman_Presentation.pdf

2) Frances Westley, Brenda Zimmerman and Michael Quinn Patton, *Getting to Maybe: How the World is Changed,* Toronto, Canada: Vintage Canada, 2007

Attachment 1: Reasons for the Failure of the Advanced Automation System

The FAA originally proposed a new project, the Advanced Automation System (AAS) in 1982 with an estimated cost of $2.5 billion, to be completed in 1996. However, substantial cost increases and schedule delays directly impacted the AAS project, which added developmental hurdles. The specific factors shared below further illustrate the greater organizational challenges MITRE needed to consider when balancing the individual and potentially conflicting objectives of the parties involved (1).

● The project began with a **design** competition between Hughes and IBM. The competition involved numerous extensions and took four years to complete. Analysis by the FAA and others pointed to inadequate consideration of user expectations and improper assessment of the technology **risks**. (Barlas 1996)

● The FAA pushed for 99.99999% reliability, which was considered by some “more stringent than on any system that has ever been implemented” and extremely costly. (DOT 1998)

● The program created unworkable software testing schedules. “Testing milestones were skipped or shortcutted and new software was developed assuming that the previously developed software had been tested and performed.” (Barlas 1996)

● There were an extraordinary number of **requirements** changes. For example, for the Initial Sector Suite System (ISSS), a key component of AAS, there were over 500 requirements changes in 1990. Because of

these changes, 150,000 lines of software code had to be rewritten at a cost of $242 million. (Boppana et al. 2006)

● IBM’s cost estimation and development process tracking used inappropriate data, were performed inconsistently, and were routinely ignored by project managers. The FAA conservatively expected to pay about $500 per line of computer code--five times the industry average. The FAA ended up paying $700 to $900 per line for the AAS software. (Gibbs 1994)

● In 1988, FAA estimated that the AAS program--both contract and supporting efforts--would cost $4.8 billion. By late 1993, the FAA estimated that it would cost $5.9 billion. Before the program was dramatically restructured in 1994, estimates had risen to as much as $7 billion, with key segments expected to be behind schedule by as much eight years. In 1994, with significant cost and schedule overruns, as well as concerns about adequate **quality**, usability, and **reliability**, the AAS program ceased to exist as originally conceived, leaving its various elements terminated, restructured, or as parts of smaller programs. (DOT 1998). Sources cited above in abbreviated form above are fully cited in foot noted

document below.

(1)https://www.sebokwiki.org/wiki/Federal_Aviation_Administration_(FAA)_Advanced_Automation_System_(AAS)

These incidents were not just technical issues, and the limited involvement and opportunities for feedback of all the stakeholders resulted in escalating problems. None of the experts or direct users pushed back on some of the unrealistic requirements,

especially the use of a new programing language. As noted in the first bullet item there was “inadequate consideration of user expectations and improper assessment of the technology risks.” At all stages of the project, limited stakeholder involvement led to the overall failure of the project. The designing and development principle of working toward a “big bang” modernization approach did not afford the cycles of learning and feedback that are critical for the implementation of a large and complex system.

Attachment 2: Specific CAASD and FAA Accomplishments 1998 - 2008

The following are some of the improvements that were made by the FAA with CAASD’s leadership between 1998 and 2008.

• CAASD led a change on how national flows of air travel were conducted. This flow management system significantly reduced delays and improved fuel use.

• CAASD prototyped in one of the ATC centers the first installed short distance conflict detection system in the world that enabled controllers to determine if there is going to be a conflict in paths between two aircraft. This system was later developed and deployed in all centers in the United States. This gave controllers the ability to detect conflicts earlier and resolve them, thus improving the efficiency and safety of the system.

• CAASD demonstrated in Alaska the first use of the Global Positioning System (GPS) for navigation and surveillance for improving aircraft flows and safety. A detailed examination of this is presented in a companion story on the Alaska Capstone project.

• CAASD was involved in the first implementation of the communications to aircraft via data communication. Data communication removes many time consuming clearances that have to be given by voice to pilots and improves controller efficiency and thus improves system efficiency.

• CAASD played an important part in the implementation of the Wide Area Augmentation System (WAAS) that significantly improved the navigation of both aviation and non-aviation systems. This system now is used not just for aviation but

for many civilian applications such as providing directions for ground travel.

• Most important, in my opinion, CAASD led the effort to move the FAA away from its “big bang” mentality to an incremental approach to functional improvements.