# The Alaska Capstone Project:

**Addressing Aviation Safety in Alaska and Improving Air Traffic Control World-Wide**

***'Everyone working on this project knows someone who has died or been injured in an airplane accident.' John Hallinan, Capstone Project Director***

This story provides a detailed example of one complex project where complexity thinking and management practices led to a major success in reducing aviation accidents in Alaska and provided a basis for a revolution in surveillance technology that was adopted worldwide. This catalyzing story is a companion piece to Moving from Complicated to Complex: An Organizational Transformation (https://plexusinstitute.org/catalyzing-stories/csp_mnk/). This story goes into more detail about the key aspects of complexity thinking and management practices that were introduced in the companion story.

## Introduction

For many decades the accident rate for small aircraft flying in Alaska was five times the national average. Alaska is a difficult environment to fly aircraft. First, it is very large and radars only cover a small portion of the state, so most of the time, aircraft are not flying in radar coverage. Second, the weather conditions are extreme and aircraft can find themselves in conditions of whiteout. "Whiteout is a weather condition in which visibility and contrast are severely reduced by snow or sand. The horizon disappears completely and there are no reference points at all, leaving the individual with a distorted orientation (1)." Third, if an aircraft goes down and there is damage to safety signal that is supposed to be broadcasting* from the aircraft, it is hard to find the aircraft and with severe weather conditions, and there is a strong likelihood that individuals will freeze to death. Finally, at most of the city and regional airports that support general aviation in the lower 48 states, there is an instrument landing system (ILS) that is a signal in space that guides the aircraft to the runway at a specific and safe angle. It enables the aircraft to approach the runway even when the pilot cannot see the runway until the aircraft is 200 feet above the runway. This is not true in Alaska for most runways.

Global Positioning System (GPS) addresses these problems. Most drivers of ground-based vehicles use this system to locate their position on the road and the system is also designed to give the driver instructions on how to get from one point to another. If we can do this with cars and trucks, then why not with aircraft? Why not determine the position of the aircraft in the air using GPS and then broadcast this position to the controller or other ground monitoring systems so that the path of the aircraft can be followed?

***ELTs** are emergency transmitters that are carried aboard most general **aviation aircraft** in the U.S. In the event of an **aircraft** accident, these devices are designed to transmit a distress signal on 121.5, 243.0-megahertz frequencies (and for newer **ELTs**, on 406 MHz).

Even if the controllers are not directing the path of the aircraft, they and others would know where the aircraft is at any time and if it went down, the location could be quickly determined. Furthermore, just as ground vehicles have roads outlined on the displays in view of the driver, routes can be displayed on the aircraft's display, along with mountains and weather patterns. Even the location of other aircraft that are broadcasting their position can be displayed. Furthermore, since GPS identifies the location of the different airports, a glide slope can be created for landing at these airports. Sounds miraculous and it is. But GPS has been around a long time. So, why wasn't it installed in aircraft long ago? Well, the problem is not quite as simple as it seems. Have you ever used your GPS and it started giving you wrong data, or the location of the destination was not where it was supposed to be? With a ground vehicle you can stop the car, get a map, make calls, and arrive safely at your destination. There is no place in the sky you can park your aircraft. So, the reliability of this system has to be nearly perfect and if something goes wrong, the pilot must be immediately informed that he/she can't rely on the system. There need to be backups in case this GPS/automation/display system fails. So, developing a highly reliable system for aircraft that alerted the pilot to failure and having backup systems was the major challenge to implementing this satellite-based system for surveillance and navigation.

The need to address the safety problems associated with Alaska has been documented for decades. But in 1999, with the leadership of former Senator Ted Stevens of Alaska, the Alaska Capstone Program (2) was initiated and finally given significant resources to address the problems associated with aviation safety in Alaska.

I was then working for the MITRE Corporation and through our research we had developed a solution to using the GPS system to display the aircraft location, along with other relevant information, to the pilot.

### The Path Forward: Thinking about Complexity

The first time I went to Alaska to the headquarters of the Capstone Project, I met John Hallanan, the Project Director. The first thing he said to me was that nearly everyone working on this project knows someone who has been injured or died in an airplane accident. The team is passionate about saving lives. One of the important aspects of developing a team to address a complex problem is to have dedicated and capable people working on the problem.

> *Capstone Project Confronts Alaska's 'Death by Airplane'*
>
> *In Alaska, more than 39 mountain ranges with towering peaks and deep gorges can ensnare aviators in sometimes fierce and rapidly changing weather, according to Airspace Magazine. When the terrain gets snowed over and ceilings drop, "it's like trying to fly inside a bottle of milk," says Elmer Webster, a 30-year veteran of the Alaskan skies. "Mix strong gusty conditions with*

*freezing rain or snow and air traffic congestion, and you have a recipe for death by airplane."*

*In the 1990s, airplanes in the state were crashing every other day, with one death every nine days. The FAA had tried education, certification and safety programs, even a zero-tolerance policy that grounded pilots for 15 days if they were caught violating a safety regulation. "None of that worked," says John Hallinan, an FAA flight standards officer at the regional office in Anchorage. What ultimately did work was the availability of federal dollars. The money enabled the Anchorage team to develop a technology-based program called Capstone.*

*Read more at https://www.airspacemag.com/flight-today/alaskas-crash-epidemic-70259395/#wvp0yFMfBvABb0pk.99*

The project team set as its major goal the reduction of the accident rate in Alaska by at least 50% using the technologies enabled by GPS. This enterprise involved multiple organizations, including the Federal Aviation Administration (FAA), the Alaska Airmen Association, commercial operators, the University of Alaska, MITRE Corporation, some avionics manufacturers, and individual pilots. In addition, the administrator of the FAA and other senior officials in the FAA saw this as an opportunity to test a technology that could eventually be propagated world-wide.

MITRE had spent several years developing a technology for aircraft that could safely and securely transmit position and velocity information using GPS from the aircraft to other users of this information, including other aircraft, air traffic controllers and flight service personnel who have the ability to follow aircraft. Locating aircraft using GPS is cheaper than radar, provides coverage in almost all areas of space (unlike radar that has a limited coverage), and provides a much more accurate position and velocity information to controllers and others. Even though this appears to be just a technical problem, it was complex because of the different partners' perspectives. Even though they all shared the same goal of reducing the accident rate in Alaska, they had different concerns. Some of these involved 1) costs of the avionics 2) privacy concerns 3) competition for existing radar technology 4) fear that the system would be deployed without adequate testing and evaluation and 5) it would not be reliable. Resolving these differences was essential to the success of this project. The differences were resolved by extensive interactions with partners and by providing information that the partners could understand: listening to their concerns and keeping everyone focused on the ultimate goal.

The new avionics was installed in aircraft in Eastern Alaska and the accident rate was reduced by 40% within several years. Furthermore, now the entire world is moving towards this technology, which will be required for aircraft in the United States by 2020. Because of this technology low-end general aviation aircraft in Alaska now have capabilities that equal or exceed capabilities that only jet aircraft have now. So, the question is, how did this team pull off such an impressive accomplishment? It is my contention that applying complexity thinking and applying complexity management principles coupled with a team of highly talented staff led to this success.

> *There was a great deal of passion among the project participants to solve the aviation safety problem in Alaska. Because of new technology and partner fears and goals, the problem was a complex one.*
>
> - *The solutions could not only help Alaska but had worldwide implications for advancement in navigation and surveillance.*
>
> - *The project was successful and applying some of the ideas that are associated with complexity management was a key component of the success.*
>
> *These ideas are highlighted in the rest of this story.*

## Applying Complexity Thinking and Theory to Managing this Project

Though we did not know much about complexity thinking, there were some key management practices associated with complexity thinking that the team used to guide this project to its success. They are listed below:

1. Network-oriented and non-hierarchical ways of operating;
2. Early and constant involvement of the right partners and asking the right questions;
3. Rapid prototyping and learning;
4. Trusting the people who do the work and risk taking.

These are a subset of the principles that were discussed in the companion complexity story mentioned in the first paragraph of this story.

## Network-oriented and Non-hierarchical Ways of Operating

The obstacles and issues facing this project were large and complex. The project would have taken forever if all decisions and information had to go up a chain of command. Figure 1 is the classic organizational structure. Figure 2 is a network structure that emerged as the project progressed. *What is interesting is that the formal organization still remained mostly as presented in Figure 1(with the addition of outcome leaders) but the operational structure of this project followed the network structure presented in Figure 2*

**Figure 1. Classic Organizational Structure**

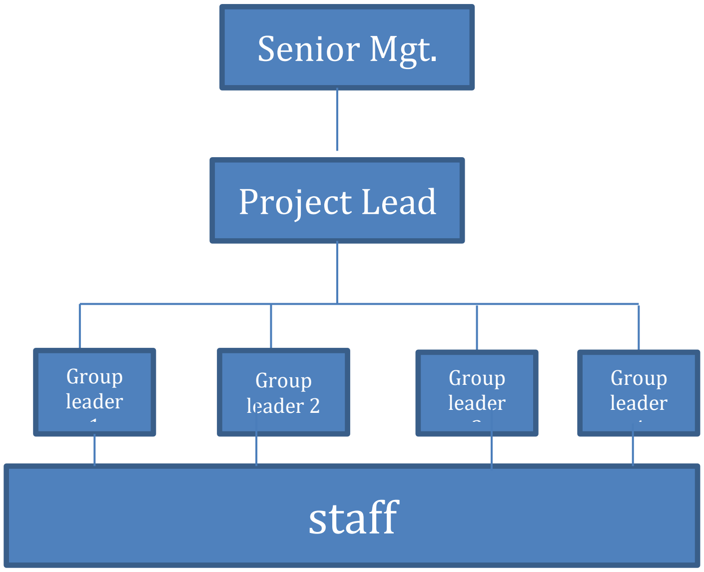
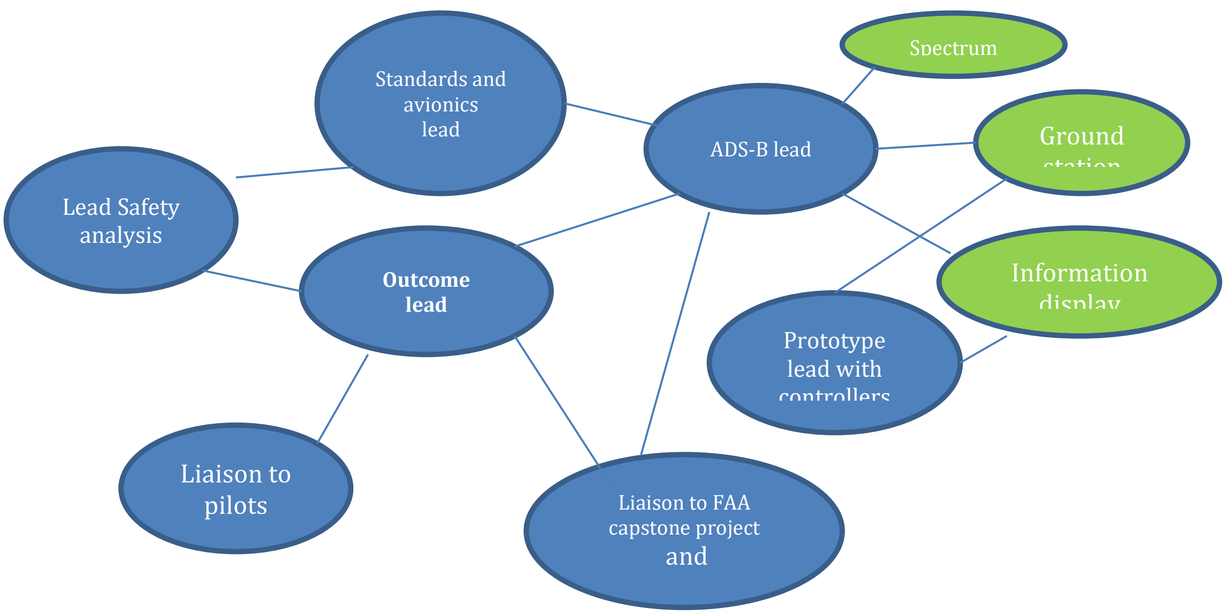



**Figure 2: Network Organizational Structure**



My job as outcome leader became much more about understanding the key issues and resource constraints and making sure that communication was flowing properly within and outside our organization than in managing the day to day activities of the staff. My role was also to facilitate the resolution of problems and issues that emerged as the project proceeded. Unlike in a hierarchical organization, I had no need to review or supervise all activities, and responsibility was devolved as much as possible to the staff.

An example of how this operational organization differs from the usual hierarchical situation can be illustrated by the following example. The MITRE liaison to the FAA capstone project (the government team in Alaska running the projection) learned that the administrator of the FAA, Jane Garvey, was coming to Alaska and needed to be briefed on the project. In the past, the project lead would talk to senior management and someone from senior management would have gone to Alaska to give the briefing. The idea that a staff member would brief the administrator would have been considered unthinkable. In our new approach, the MITRE staff liaison developed the briefing, and had it reviewed by me and a member of senior management. He gave the briefing and spent several days with Garvey showing her the elements of the project.

So, what is the difference between the two operational approaches and why is this network approach more suited to addressing complex problems? First and very important is that it is self-organizing. The people working on the project were highly skilled and dedicated. They all understood what was to be accomplished and knew enough about the big issues to know whom they needed to link up with and why. To facilitate these connections the project held meetings on a weekly or bi-weekly basis in which the individuals in the blue circles (see Figure 2) would discuss (usually without briefing charts) what they were doing, why, and what issues were emerging. This gave the entire project team an understanding of the major issues and whether they needed to be involved with them.

Something very surprising emerged from this. Individuals began to identify where they would be most useful. For example, we had someone working on an unfruitful project to put radars on platforms in the Gulf of Mexico. His skill was much more suited to working with general aviation pilots and flight service stations, and in one meeting we realized this was an area we did not have covered and it was a vulnerability to the project. He came to me (the outcome leader) and suggested that we send him to Alaska, where he filled one of the key liaison positions. This was just one of many changes that emerged from having the whole team involved. We had secretaries and support staff involved. What still amazes me today is that we had 30 people working on this project and probably 28 out of 30 were working at a very productive and creative level. This is an important point. Complexity thinking applied to organizations often requires people to rise to the challenge, whereas people under a more hierarchical operating approach often voice their objections by slowing down their work or losing their motivation because they are not valued or listened to.

Again, this is not necessarily a structural change to the organization. Even though MITRE had a formal hierarchical structure (president, division directors, program managers, outcome leaders and staff), a new communication and networking approach was implemented for this project. I have reflected on how this networking organization emerged. Since we realized that we had to interact with so many partners, it became impossible for one or a few individuals to create all the connections. We had to create linkages with many staff members. But we also learned that the resulting interaction between one partner and a staff member would have an impact on the project, and the interactions among our staff also had to change. That required that the information flow had to increase significantly and had to be timely.

Our team learned that complex problems required a type of communication and relationships that are better facilitated by a network culture, a trust in staff, and a belief that individuals can self-organize to get the job done, rather than having a top-down solution imposed on staff. The concepts are easy but the skills needed to effectively collaborate and communicate across areas of expertise are not easy. As I often say, with complex problems, the technology is often the easy part even though new technology is difficult to introduce into systems. Bringing the technology in line with the needs of the partners, and considering their fears, desires, and pressures, is what makes this endeavor complex. Also, people have to let go of their egos. The director responsible for this project at MITRE had to avoid a trip to be with the administrator of the FAA because he was not the right person to do that job and he had to not feel threatened that he was losing his importance in the organization. The director had to address his fear that he was not fully in control of the situation- which in itself is an illusion.

> *We learned that dealing with a much larger set of partners required a different way of operating (a networked approach) and this then led to a different way of communicating.*
>
> *This new way of operating led to staff being able to more readily self-organize by being able to determine where the needs were and how they might meet these needs.*
>
> *By working with management, the skills of the staff met the needs of the project. Higher level management had to learn how to relinquish control and put more trust in staff.*
>
> *This new approach along with the passion for the project led almost all staff operating at a very high level of performance.*

**Early and Constant Involvement of the Right Partners and Asking the Right Questions**

When I started my career at MITRE, it was led and managed by very highly technically trained individuals. These individuals believed that they understood what the future air traffic control system should look like. They knew the technology and had very advanced ideas on how the future system should work. Even in the early 1980s they had envisioned a system that worked with controllers overseeing a system that was almost fully automated. Computers would track aircraft; they would identify conflicts and the computer algorithms would determine the best routes for the aircraft that avoided conflicts. MITRE was not alone. NASA had a set of researchers working on similar concepts for nearly 30 years. Here we are in the year 2017 and we are not close to this vision. How could we have been so wrong?

The answer is that we often assume away the most complex aspects of problems that needed addressing. For example, the engineers and human factors people developed demonstrations that put controllers in front of a controller's workstation. The controllers would observe the display and the computer algorithms would determine if there was going to be a conflict between two aircraft or the aircraft and unacceptable weather and would redirect the flights to the most optimal paths to avoid these conflicts. would be avoided. Sounds great! But, not so fast. What will keep the controllers alert? What keeps their skills up if the system fails and they have to fall back to providing this service without the computer algorithms? If this capability will enable handling more traffic (which it promised to do), can controllers cope with increased traffic if algorithms fail and they suddenly have to rely on their own knowledge? The requirements for aviation safety are extremely high and to meet these high requirements there is very rigorous certification of the software. This kind of verification has been done on avionics systems in aircraft but never on ground systems. Since ground systems change often, how will this certification be achieved? So, even though controllers were brought into the process, they were not asked some of the most important questions. Safety specialists were not consulted and non-technical issues such as job security for controllers or pure boredom were not adequately addressed.
How could such basic questions be missed and not addressed? I could provide so many examples of where the hard issues are assumed away and the narrow issues are researched. I believe this comes from viewing problems from a limited perspective and expecting situations where everything goes right and humans operate like computers.

Avoiding this myopic analysis can only be addressed when 1) we bring in all the partners ;2) we encourage asking the right questions; and 3) we are open to alternative paths to improving the system rather than proving a preconceived concept. Why are such obvious questions ignored? That is a difficult question to answer. My take is that people become attached to their ideas and subconsciously they often find the really difficult questions and issues are impediments to the progress envisioned. How did the Capstone project associated with Alaska aviation safety escape this trap? As mentioned above and repeated here, the project was designed to include the multiple partners (partners are people or organizations that have a stake in the system's evolution).

"The **Capstone Program** was a United States government-funded aviation safety program for the state of Alaska, primarily focusing on rural areas of the state. This joint effort – between the Federal Aviation Administration (FAA), the Alaska Pilots' Association, commercial operators, the University of Alaska, MITRE Corporation, some avionics manufacturers and individual pilots – cut the accident rate in the eastern part of Alaska by around 40%. The program ran from 1999 until 2006, when the FAA integrated it into the national automatic dependent surveillance – broadcast (ADS–B) program (2)."

Notice how many of the partners were actually included in the definition of the objectives and execution of the project. Also, the project management team had the foresight to listen, understand the key problems that were brought up by the partners, and address them. Management was open to putting all the issues on the table.

*Difficult issues are often assumed away and unaddressed in projects and research. Reasons include:*

- *Lack of adequate stakeholder involvement*
- *Narrow focus of researchers because of deep knowledge in a limited area*
- *Fear that delving into difficult issues will impede goals for implementation*

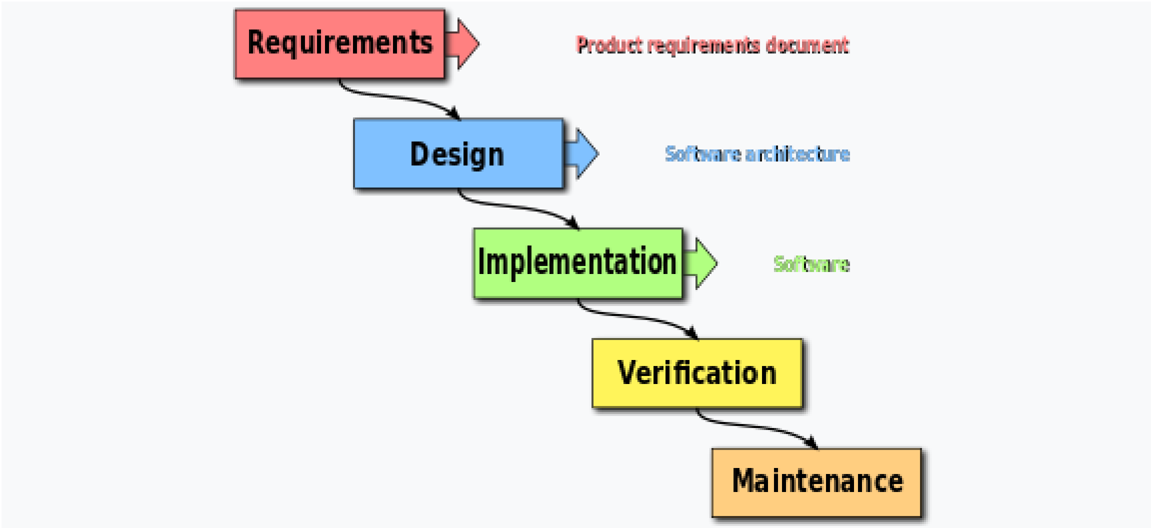
*Including all partners and involving them in research throughout the project helps maintain focus on all elements of an initiative.*

*All stakeholders need courage not to duck difficult issues.*

## Rapid Prototyping and Learning

When I began my career, computer software development followed a traditional waterfall model. Wikipedia defines the waterfall method as follows:
"The waterfall model is a relatively linear sequential design approach for certain areas of engineering design. In software development, it tends to be among the less iterative and flexible approaches, as progress flows in largely one direction ("downwards" like a waterfall) through requirements development, to design, to implementation, then verification and then maintenance (see Figure 3) (3). "In common practice, waterfall methodologies result in a project schedule with 20–40% of the time invested for the first two phases, 30–40% of the time to coding, and the rest dedicated to testing and implementation. The actual project organization needs to be highly structured. Most medium and large projects will include a detailed set of procedures and controls, which regulate every process on the project.

**Figure 3: The Waterfall Model**




This was an excellent model in a time when prototyping was difficult and expensive, but it has some very serious flaws. In the aviation business, these flaws were illustrated by the failure of the modernization of our air traffic control system in the mid and late 1980s. Two and a half billion dollars went into the development of the Advance Automation System (AAS) (4) that was supposed to replace the computer hardware and software throughout the ATC system – including controller workstations, and enroute, terminal, and tower air traffic control facilities.

AAS was intended to provide new automated capabilities to accommodate increases in air traffic. It followed the waterfall model but the problem was that the requirements could not be tested prior to development and certain design concepts were too immature for implementation at this stage of computer/software development. For example, a new programming language was used and most programmers did not know how to program effectively with this language. Distributed database processing was in its infancy and was an important part of the program. Requirements were set unrealistically high so that design became impossible. Unfortunately, these problems were discovered only after the implementation and verification stage. This was about six years into the project, and by that time, no one had the desire to reinstitute the project. Now the system is being modernized by many incremental steps.

A different methodology for system/software development has now emerged and these align with many of the management principles of complexity theory: According to Wikipedia the principles are as follows:

The *Manifesto for Agile Software Development* is based on twelve principles (5):

1. Customer satisfaction by early and continuous delivery of valuable software
2. Welcome changing requirements, even in late development

3. Working software is delivered frequently (weeks rather than months)
4. Close, daily cooperation between business people and developers
5. Projects built around motivated individuals, who should be trusted
6. Face-to-face conversation, the best form of communication (co-location)
7. Working software as the primary measure of progress
8. Sustainable development, able to maintain a constant pace
9. Continuous attention to technical excellence and good design
10. Simplicity—the art of maximizing the amount of work not done—is essential
11. Best architectures, requirements, and designs emerge from self-organizing teams
12. Regularly, the team reflects on how to become more effective, and adjusts accordingly

These principles were applied to the Alaska Capstone Project. Over a period of several years, the MITRE Corporation sponsored a research program that prototyped an avionics system that allowed an aircraft's position and velocity to be broadcast to the ground and other aircraft, and for weather information to be broadcast to the aircraft. In addition, terrain maps were included in the avionics and the position and altitude could be superimposed on the display. Thus, even in bad weather, the pilot could have situational awareness of the terrain. When the Capstone Project was getting off the ground, MITRE had an opportunity to demonstrate this capability to multiple partners. Modifications were made and a full-fledged demonstration was conducted with prototype avionics and ground stations. Requirements were then developed, but rather than using the waterfall model, they were developed with a completed prototype system and could be modified with improvements to the prototypes. The system requirements were passed on to avionics manufacturers, a limited set of avionics was installed in over 200 aircraft, and a limited test was completed. Data was collected and feedback was obtained from all the partners--controllers, pilots, avionics manufacturers. This led to full-scale development and deployment. Most of the principles of Agile were followed. This was done early in 2000. Now 19 years later the entire world is adopting the technology tested out in Alaska along with modifications to support commercial transport aviation.

> *For a complex system it is impossible to understand all the variables and requirements before testing out solutions. So, the solutions emerge as one proceeds in the project. Modern communication and simulation technology make this trial and error approach much more affordable.*
>
> *It is necessary to involve the partners in setting the criteria for the prototypes and in the evaluation of their results. The learning times between upgrades needs to be short. Principle 12 of agile: "Regularly, the team reflects on how to become more effective, and adjusts accordingly," is an essential part of a true learning culture with the expectation that failure leads to learning.*

## Trusting the People Who Do the Work and Risk Taking

One of the Agile software development principles is: projects are built around motivated individuals, who should be trusted. For me, this is one of the key principles of complexity thinking. With the decentralized model we can receive more information. But how does the organization make decisions based on this information? This is where a blend of a distributed and hierarchical networks comes in. Information (now that we have computers and the internet) can be distributed to members of the team rapidly and responses to this information can be obtained rapidly. The issue often involves only a few key individuals who have a stake in the decision and these individuals meet. If there is no consensus, hierarchy matters. This hierarchy enables decisions even if the team is not settled on a path. But the decisions are made only after relevant members of the team have their say. Who makes the decisions? This is related to the criticality of the issue. To explore this, I will provide an example that came from the Alaska project.

One of the tasks we had in the Alaska Capstone project was to evaluate the changes in safety resulting from installing avionics in over 200 aircraft. After two years of operations with the new equipment, we were able to evaluate the accident rates associated with these 200 aircraft compared to the historical record without the avionics. It was not a straight-forward analysis, since we had to consider whether there were different conditions in the two years from the past. We also had to make sure that the sample size was large enough to draw conclusions. As the study was wrapping up, we were informed that Senator Stevens was going to a conference on this Capstone project in two days, and he wanted our safety data. We did not have time to do an extremely thorough analysis of the team's results. If we didn't present Senator Stevens with the results, that would have dampened the momentum of the project and would have disappointed Senator Stevens. If we gave him incorrect information, we would have embarrassed our company and potentially hurt the project.

I met with the team evaluating safety. We discussed what they did, and I asked numerous questions. I then asked the team lead what he would do and how confident he was of the results. He assured me that they were good. There was enough data to provide a statistically significant result. With that assurance, I took the results to my division director and asked him to sign off. He questioned me and was satisfied with the answers. On the day of the conference we delivered the results to Senator Stevens, and he presented them to the conference. This was a case of hierarchical management (because the final decisions were made at the highest level) with sufficient input from staff so that reasonable risks and benefits could be evaluated.

In our previous culture at MITRE, this would never have happened. The process would have required months of reviews by both MITRE management and lower levels at the FAA. In this new culture we could act more quickly while maintaining a good measure of quality control. We trusted staff to do the right thing.

*This story illustrates the operating principles of a hybrid bottom up and top down approach to decision making.*

- *Staff's work is questioned but trusted.*
- *Staff is involved in making recommendations to management and in presenting the information relevant to decision making.*
- *Staff members are asked for their honest opinions and feedback.*

*Management still made the decision in this important case, but often in cases where the decisions are not as critical, they are made directly by staff with or without management input.*

## The Results

This project had a major impact on the safety of aviation in Alaska and also contributed to the world-wide adoption of the GPS based technology for navigation and surveillance. The Capstone Project was recognized by the aviation industry when we and other partners received the "Collier Award in 2007. The Collier award is an annual aviation award administered by the U.S. National Aeronautic Association (NAA), presented to those who have made "the greatest achievement in aeronautics or astronautics in America, with respect to improving the performance, efficiency, and safety of air or space vehicles, the value of which has been thoroughly demonstrated by actual use during the preceding year(6)."

My view is that the success of this project had several causes. First was the foresight of Senator Stevens to obtain funds for this project. Second, the realization that this was a problem that needed a new approach and third, the dedication of the people to the mission and finally how MITRE/CAASD, the program office and partners managed this project and how they related to each other. This complexity story illustrates how complexity thinking and management can lead to amazing results.

Endnotes

(1) Whiteout definition https://en.wikipedia.org/wiki/Whiteout_(weather)

(2) Wikipedia writes, "The **Capstone Program** was a United States government-funded aviation safety program for the state of Alaska, primarily focusing on rural areas of the state. This joint effort – between the Federal Aviation Administration (FAA), the Alaska Pilot's Association, commercial operators, the University of Alaska, MITRE Corporation, some avionics manufacturers and individual pilots – cut the accident rate in the eastern part of Alaska by around 40%. The program ran from 1999 until 2006, when the FAA integrated it into the national automatic dependent surveillance – broadcast (ADS–B) program. https://en.wikipedia.org/wiki/Capstone_Program

(3) The Waterfall model https://en.wikipedia.org/wiki/Waterfall_model

(4) Baseline: The ugly History of Tool Development at the FAA (2002-04-09) http://www.baselinemag.com/c/a/Projects-Processes/The-Ugly-History-of-Tool-Development-at-the-FAA

(5)Agile software development https://en.wikipedia.org/wiki/Agile_software_development

(6) The Collier Trophy https://en.wikipedia.org/wiki/Collier_Trophy