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Introduction

We are still more than a thousand days short of the Year 2000 -- 1,208 to be precise -- and there is already a steady stream of speculation about what the next century will hold. But unlike the unbounded confidence of the previous century, the dominant theme today seems to be a dawning sense of our limitations.

The current edition of *Books in Print* lists more than 150 books entitled *The End of* -- something or other.

One of these is typical of the genre. It's called *The End of Science*, and the author -- John Horgan -- makes the case that pure science has entered an era of diminishing returns. The age of great scientific discoveries is behind us, Horgan argues. The big problems that can be solved have already been solved, and the big ones that haven't yet been solved may never be solved. Science is now bumping up against impassable barriers to further progress. Future advances in knowledge will require larger and larger investments yielding smaller and smaller gains.

As frustrating as this may seem, the recognition of limits is also having a profound liberating effect, especially for those of us charged with the responsibility for aviation safety.

For, paradoxically, the recognition of limits is the first crucial step in surmounting those limits. We are emboldened to try ideas which once seemed too radical and visionary to ever be achieved.

The widespread awareness of limits is one of the defining characteristics of our times. Exploiting this knowledge to bring about far-reaching change is to realize the latent potential of the moment. Finding the most rewarding payoffs in an era of diminishing returns is one of the great management

challenges of our age.

Today I will discuss the FAA's recent efforts to leverage change in three situations where progress seemed to be stranded and stalemated.

I will describe how, in each of these three areas, the FAA has attempted to surmount its limitations -- not through fine-tuning and incremental improvement, but by fundamental restructuring of the underlying situation.

I. Aviation Safety: getting off the plateau.

The clearest way to demonstrate the idea of limits is to show this graph of aviation accident rates in the U.S. from 1946 to the present. You find the same pattern for western Europe, I believe.

[Slide #1: Accident Rates Per 100,000 Flight Hours]

There has been a generally downward slope of the rate since the late 1940s.
The trend is quite consistent, with each new peak tending to be lower than the preceding ones, and each trough deeper than those before.

Finally, in the mid-80s, the line flattened out as the rate stabilized at the current low level of accidents. Air travel is not getting any more hazardous, but neither is it getting any safer. We've settled on a plateau. We seem to have reached a limit.

The greatest progress in reducing aviation accidents was made from about 1950 to 1965. One of the worst years during that period was 1960, when there were slightly more than two accidents per 100 thousand flight hours. If that rate had remained unchanged, we would have had at least 240 accidents this past year, and a fatal air crash every ten days.

That such a calamity was averted seems to me to be one of the most remarkable achievements of the post-war era Even though air travel was experiencing enormous growth, doubling five times during this period, the rate of accidents sharply declined.

It is also remarkable that the major advances in safety occurred in fairly quick succession.

The first major advance occurred with the introduction of jet aircraft. Manufacturers quickly learned to build stronger but lighter airframes using new materials such as nickel alloys, titanium, and spun glass.

The introduction of jets also reduced the incidence of engine failure. Before 1958, the United States averaged three hull losses and 43 fatalities a year from accidents caused primarily by engine failure. Since 1958, there has been only one major accident. The second generation of jets phased in during the mid-sixties virtually eliminated inflight shutdowns.

[Slide 2. Mid-air collisions in the United States, 1946-1986]

Another hazard during this period was mid-air collision. One especially catastrophic incident occurred in June of 1956 when two aircraft collided in uncontrolled airspace over the Grand Canyon. All 128 passengers on board the two planes perished, setting a new record for fatalities in a single air accident.

Within weeks, the U.S. Congress provided the money to set up a system of long-range radar sites to cover the entire country, and established the FAA to manage the domestic airspace.

The newly-formed FAA almost immediately began to plan for the automation of en route air traffic control. This was the most complex computer application anyone had ever attempted, so there were no precedents. Its half million commands required more than twice the amount of memory originally planned, a complication which caused the project to fall behind schedule. This is a familiar story to anyone who has ever undertaken large-scale automation projects. The first installation of IBM's prototype 9020 system took place in 1967. It would take the FAA almost 10 years to complete the work at all 22 en route centers.

Despite the delays, positive control of the airspace produced considerable success in reducing the number of mid-air collisions. By 1961, the threat had been confined to one danger zone -- the congested airspace around busy airports.

These were virtually eliminated when the FAA required commercial aircraft entering certain designated terminal areas to be equipped with two-way radio, transponders and a receiver. Over the years, these restrictions have been broadened, with the result that a decade has now passed without a midair collision in the United States involving commercial airliners.

[Slide 3. Controlled Flight Into Terrain, 1946-1996]

The milestones that mark the history of aviation safety are often high profile accidents which instill a sense of urgency.

The Grand Canyon midair collision is one example. Another occurred on a rainy day in December 1974 near Dulles International Airport outside of Washington. A jet with 92 people aboard was making a normal approach when it slammed into a hill. That accident was traced to several causes, one of which was the absence of a cockpit alerting system to warn the crew that they were dangerously close to impact.

As a direct consequence of that accident, large commercial aircraft were required to be equipped with a ground proximity warning system that sounds an alarm whenever a plane flies too near terrain. Until the Cali accident in December 1995, the Dulles crash was the last instance by a major U.S. carrier of a "controlled flight into terrain" -- eliminating a category of accident which, between 1946 and 1974, had occurred 72 times. It is still the leading cause of accidents worldwide.

What I have reviewed are some of the major events leading to gains in aviation safety in the United States. These are the advances which removed many of the most serious hazards to air travel, and brought us to the stable baseline established in the mid-eighties.

[Slide 4. Advances in Air Traffic Control]

This next illustration shows the important linkage between air traffic control technology and safety. Many of the principal gains in aviation safety in the past two decades are due to the adoption of new technologies that share a common characteristic: they increase the level of vigilance in the cockpit. Satellite navigation, digital data link, collision avoidance systems, and on-board automation are all logical extensions of this trend. And all are being actively pursued by the worldwide aviation community.

There are now about 60 Boeing 747's operating over the Asia Pacific routes that are equipped with future air navigation system (FANS) package of avionics for satellite navigation, data link communications, and automation.

Last fall, controllers at the FAA's center in Oakland, California, began offering satellite-based data link communications to flights operating over the southern sector of the pacific Ocean. By the end of this year, FANS-equipped aircraft in flight between Sydney or Auckland and the United States will be able to use satellite data link for automated rerouting. Adverse wind and weather conditions can be circumvented, saving up to 20 minutes of flying time and about a thousand gallons of jet fuel per flight.

Apart from the savings in time and fuel, controllers and pilots now have direct, two-way communications over the oceans. This was not possible before the advent of satellites and digital data link communications.

Since 1993, all commercial aircraft with more than 30 seats are required to carry an enhanced version of the collision avoidance system, which we call TCAS-II, in order to fly in the United States. That includes the more than 100 foreign carriers that operate scheduled passenger service to our shores. TCAS II is a proven technology that has logged over 50 million hours of operation worldwide. I understand that, within four years, TCAS will become mandatory in Japan and in the 33 countries which are part of Eurocontrol. Similar measures are being considered by Australia and New Zealand. As the adoption of TCAS widens, the threat of midair collisions will certainly decline even further.

But other problems remain to sporadically menace air travelers. In the

same year that near midair collisions dropped in the U.S., runway incursions increased. Wind shear and wake vortex can still have lethal consequences, and human error is a continuing concern.

In May, we began evaluating a new system at San Francisco International Airport to alert controllers to potential runway incursions. We call this system the airport movement area safety system, or AMASS. Thirty-four of the busiest airports in the United States are getting this new system. It is one of the industry's most-wanted safety initiatives.

Doppler radar, like those we are installing at 45 airports, virtually eliminates the threat of undetected wind shears. And we recently increased the separation standards for all aircraft operating in the United States to reduce the risk of accidents caused by wake turbulence.

But progress in all these areas, important as they are, will have only a limited effect on the overall accident rate. Because the rate is already so low, there is less opportunity to achieve the big reductions of the past. We will have to work twice as hard for each extra increment, each additional gain.

My colleague David Hinson, the FAA Administrator, sees this situation as analogous to golf It is fairly easy to get under 100 if you take some lessons and play once in a while. With a little more investment and a little more practice, you can get to 90. With still more effort, maybe you can get to 80. But if you are ever going to reach 82, you have to work very hard. Shaving those last five or ten strokes off your game takes a disproportionate investment.

Clearly, the current approach to improving safety has reached the point of diminishing returns. It is time to try a fundamentally new approach.

Up till now, much of our knowledge of aviation safety has come from accident investigations. We learn a great deal from picking up the pieces. Especially critical in the search for clues are the data retrieved from flight and voice recorders.

But the data on these recorders, captured routinely during the course of every flight, could also help us more clearly define what we mean by safe

flight.

As it is, almost nothing is known about what happens during the hundreds of thousands of flights which each day arrive safely at their destinations. Data descriptive of routine operations would enable us to establish statistically valid norms of safe performance, and to quantify the levels of risk associated with ordinary flights. We could more precisely pinpoint those circumstances which are potentially hazardous.

With the advent of more advanced flight recorders which constantly monitor as many as 200 parameters processed by onboard flight management systems, we have an veritable torrent of safety-critical information which was never before available.

Exploiting this resource will not be easy. There are serious legal and administrative issues which must be successfully negotiated. Beyond the difficulties of access, powerful new tools of analysis will have to be developed to handle this overwhelming mass of data. It is a formidable intellectual and technical challenge. And it will require the FAA to seek new collaborative relationships with the carriers as well as with its counterpart agencies around the world.

An undertaking of this magnitude would, in normal times, likely be delayed by the press of other business, competition from other projects, or because the task just seems too hard.

But these are not normal times. In a field as dynamic as aviation, we cannot allow aviation safety to lie dormant. The use of flight recorder data for prediction and prevention marks an important conceptual shift which opens up a wealth of new possibilities. It is an asset which must be tapped.

II. Air Traffic Modernization -- the limits of project management

The second topic I will discuss today also involves accident research, in a way. It is an examination of a major mishap in project management. I refer to the Advanced Automation System, the FAA's multibillion dollar effort to modernize and upgrade its air traffic control computers.
It was my responsibility to delve into the details of this venture, and decide

what could be salvaged.

I know we tend to be skeptical that government agencies ever really correct their ways. We all have heard Peter Cook's line that "I've learned from my mistakes and I'm sure I could repeat them exactly." It did seem that many of the difficulties the FAA encountered in its first automation project were revisited in the second.

However, the outcome this time could be truthfully called a revolution. For a new regime came into being April first of this year.

The most important internal change in the FAA's 38 year history can be traced to events related to the Advanced Automation project. The project was so seriously flawed in execution that it became clear to everyone that major reform was long overdue.

The Advanced Automation was begun in the early 1980s to replace computers which the FAA had relied on for twenty years. The project was intended to retire hardware which was obsolete and becoming increasingly hard to maintain.

I'm sure many of you have heard that the FAA is the largest consumer of vacuum tubes which we still import from Poland. Lately, I suspect, we've had to import even more because they're much in demand as stage props. Just about everyone who makes a speech about the problem wants to show one to the audience. Many people have never seen a vacuum tube -- it's becoming an historical curiosity you'd expect to see exhibited at the Smithsonian or the Victoria and Albert.

Beyond replacing these outworn relics, the Advanced Automation project had another ambitious aim -- to introduced highly advanced concepts of automation to the field of air traffic control.

Automation was intended to integrate radar, communications and sophisticated decision support systems throughout the air traffic control system-- from the airport towers to the en route centers located across the United States. The original program called for the writing of more than a million lines of computer code.

Almost from the start, the Advanced Automation program fell behind schedule and ran over budget.

That, of course, is not unusual. In a survey of 120 organizations here in the UK, it was found that more than 60 percent have had runaway projects which failed significantly to deliver on their promises or which exceeded budgets by at least 100 thousand pounds.

Another well-documented example is the Aramis Project to develop a Personal Rapid Transit system for Paris. The idea was to build miniature railroad cars that would take you from any station to your destination without a transfer. The French government devoted 500 hundred million francs and eighteen years of research effort before finally giving up. There is one byproduct of Aramis -- those two car robot trains that carry passengers at airports. But otherwise the project revealed only one lesson. According to an expert who wrote up its history, "Don't innovate in every respect at once."

That's a lesson which, if heeded, would have saved the FAA a lot of grief.

By the time the program was curtailed two years ago, the FAA had spent 2.3 billion dollars and was facing a total bill which could have exceeded 7 billion. More than a billion dollars had been invested in just one component -- a state-of-the-art workstation for controllers.

While much of the work was technically sound, the work proceeded so slowly that it was in danger of becoming outdated while it was still being developed.

Part of the problem was endemic to the federal bureaucracy.

Our procurement policies were originally intended to keep crooked horse traders from cheating the U.S. Cavalry. Over the decades, the regulations had grown more and more complex -- more and more costly and time-consuming to carry out. They were effective in assuring that the government got the best deal on paper clips and dust bins. But they were not suited to procuring state-of-the-art technologies.

As a result, the FAA was constantly trying to catch up by engaging in

mid-project redesign -- adding on features as we learned about them ... modifying old plans to exploit new possibilities.

The contracting and project management cycles seemed forever out of phase, and neither could keep up with technological advances.

It was as if we were buying a 1996 model automobile, but kept ordering all the new options that the car magazines promised would be available in 1997.

In the end, the FAA decided to go for basic transportation. We cut the program back to manageable proportions -- identifying what was essential and achievable, postponing or terminating everything else.

In the aftermath, we conducted or commissioned more than 100 studies and reports to try to learn what we could from this deeply frustrating experience. There were more than a dozen fundamental faults in program management identified by these post mortems.

The most important failing was a weakness in analyzing requirements. Deliberations about what the system had to do went on for months, while the clock ticked and the costs mounted.

The second most serious fault was that managers consistently underestimated the complexity of the task and the level of effort required to do the job. The end-result was reactive, crisis-driven management.

The underlying problem was that we had reached a limit in our ability to manage complex technology-driven projects. Difficult under ideal circumstances, a cumbersome contracting procedure made the task almost impossible.

But diagnosis is not a cure. Without some basic changes in the way we conducted our business, we were destined to relive this history and repeat our mistakes. Reform of procurement had to be tackled before we could improve the quality of management. Just such fundamental reform took effect this past April.

The FAA is now one of a very limited number of United States government

agencies free to write its own procurement regulations.

We have streamlined the process, stripping out the fine-print and clearing away the arcane conditions.

We have coupled our new procurement procedures with a new philosophy of acquisition. We are moving away from our decades-long reliance on massive projects built to our specifications. We are shifting to an open, modular architecture in which the FAA defines broad system requirements, and then shops in the marketplace for off-the-shelf components which best fit our needs.

The FAA benefits in buying the latest technology at competitive market prices. We also create opportunities for small companies -- those producing products which are often on the leading edge.

III. Paying for Progress : the limits of government financing

The long struggle to win approval for procurement reform is a reminder that the problem of diminishing returns is often closely related to size and complexity. It is far easier to induce rapid change in an institution which hasn't been around for a long time. History severely constrains change. Over the years, as an institution grows it becomes more complex and more sclerotic.

Conservatism is, in fact, an admirable and necessary trait in organizations charged with important public responsibilities.

The FAA's efforts to modernize its air traffic control system had to proceed with considerable caution. Old technology could not be simply "traded in" for a new model. Neither could the old system be shut down while the new was installed. Innovation had to be approached with wariness.

The challenge has been to phase in new technologies without risk to safety or disruption of the essential services provided by the most complex aviation system in the world.

As you know, the size of the U.S. airspace is roughly comparable to all of Europe, and it handles 50% of the world's aircraft operations. Five of the

ten busiest airports are located in the States. One of our states, Ohio, has more airports than all of China.

In the past 50 years, air travel has grown from 13 million passengers a year to 550 million. In 15 years or less, this number will double.

An industry of this scale has an enormous economic and political stake in what the FAA does and how we do it.

One of the characteristics of modern societies is the proliferation of organized interest and advocacy groups which often resist change. And if the change involves money, it becomes even more difficult to achieve. In just about every country on Earth, the competing demand for dwindling resources -- is an enduring problem.

As a government agency, the FAA receives it funds through appropriations by the United States Congress. The annual budget battles in Congress make long-term planning extremely difficult, since we can never be sure how much money we will receive from year to year.

Our budget has been declining in real terms at the same time that we are trying to upgrade our air traffic control system, step up our safety inspections, support an ambitious program of research, and meet the growing demand for our services.

Caught in this untenable position, we began a search for alternative funding sources which would provide a stable, predictable flow of revenue to the FAA.

To many, the most reasonable option was to charge fees to users of the system. The larger carriers supported this proposal, but the low-fare airlines strenuously objected. They believed these added costs would have to be passed on to their passengers, making them less competitive. Or their costs would have to be absorbed, making them less profitable -- even unprofitable.

The opposition of our very large general aviation sector to any system of user fees exacerbated the problem even further.

The confusion was further compounded by the failure of Congress to renew the 10% tax on airline tickets which for years has provided funds for airport improvements. What was once a multibillion dollar reserve was quickly being depleted. Congress has recently passed a short-term renewal of the tax. But the more complex issue ... finding a stable source of funding for the FAA ... is still unresolved. Congress will take this up, once again, when it returns to Washington in the fall.

Conclusion

The argument I have put forward today frankly acknowledges that, on many fronts, we are approaching the limits of our capabilities. Policies and practices which have served aviation so well up till now, have exhausted their effectiveness.

It is equally true that in each of the three cases I have discussed, the recognition of our limitations has spurred us to search for new, even radical approaches, which would help us maintain our momentum.

Those of us who deal with aviation issues from a global perspective are also increasingly aware of the limitations of solutions which are narrowly national in their scope. The idea of globalization has been dismissed, by some economic writers, as little more than confused thinking and media-inspired hype.

They haven't looked closely at what is happening in aviation, where there is an accelerating trend toward greater integration, consolidation, and the harmonization of standards.

One of the factors forcing nations to coordinate their efforts is a mounting concern over safety.

I mentioned earlier in my talk, that the accident rate in the U.S. had, by the mid-1980s, stabilized at its currently low level.

However, we can ill afford to be complacent when we think through the implications of the expected growth in air travel over the next decade or two.

A study by the Boeing Company shows just how urgent it is that we keep raising the level of safety.

[Slide 5: Boeing forecast of projected hull losses]

According to this study, we can succeed in keeping the accident rate as low as it is today, and still suffer calamitous consequences over the next 20 years. As air travel grows so will the number of hull loss accidents, even though the rate remains unchanged The Boeing projection indicates that, worldwide, we must anticipate one crash a week. The acceleration could begin as soon as four or five years from now and continue to climb thereafter.

I hardly need to point out the national trauma of even one major air disaster a year. One a week somewhere in the world is unthinkable.

When a plane goes down today, it is likely to be carrying passengers from a number of countries. With the surge in world tourism and the economic advantages of airline code-sharing, there will be a growing demand for uniform standards strictly enforced. No national government will be able to disregard the safety of its own citizens when traveling abroad, regardless of the carrier.

It was this concern that led the United States to evaluate the safety of foreign carriers flying to and from our airports. Like the vast majority of civil aviation authorities through the world, we at the FAA believe that when travelers choose an airline, they should be able to assume that the carrier adheres to at least minimum safety standards. Nevertheless, the Safety Oversight Program was not without controversy, especially the decision to make our evaluations public.

We knew this action would evoke concern from some civil aviation authorities, and -- of course -- it did. But while the United States chose to confront the issue, we never thought that unilateral action would be sufficient.

We have always advocated a coordinated international effort, and fully support the decision of International Civil Aviation Authority (ICAO) last October to establish an Aviation Safety Oversight Program. The United States has given financial and technical backing to the program, which got underway in March. We will continue to make every effort to assure its success.

We have reason to be optimistic. ICAO reports that, last year, there was a 25 percent decline in passenger fatalities in accidents involving scheduled airlines, and a 33 percent drop in the accident rate per 100 million passenger-kilometers.

In announcing these encouraging statistics, Dr. Assad Kotaite, council president of ICAO, warned that despite the implementation of strong regulatory programs, many preventable accidents continue to occur.

President Kotaite went on to observe that "the limitations of regulatory safety measures are widely recognized," and that it was important for member states to explore other approaches.

This is precisely the point I have been emphasizing today.

We may be reaching the limits of what can be achieved with our current policies and practices. To break through these limits and make further progress in aviation safety, the effort must be international in scope.

Aviation safety is an issue which daily confronts civil aviation authorities everywhere in the world.

It will be a dominant concern tomorrow for many of you -- the next generation of leaders being trained here at Linacre College.

Thank you very much.