AN AIRCRAFT MANUFACTURER'S VIEWPOINT: WHO'S IN CHARGE ANYWAY?

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My job this morning is to present the viewpoints of an aircraft manufacturer on future airport and airspace operations. The organizers have suggested that some particular elements will be of interest to you: cockpit technology, aircraft operational capabilities, human factors, and role of aircraft and pilots.

That's what I have done. I have enjoyed the chance to take a broader view than circumstances commonly allow. Yet in preparing I was persuaded time after time that there are problems beyond technology which are the real limitations. So I'll also speak about the people -- who we are, what we're trying to do, how we know what to do, and who's in charge. That accounts for the title.

We live and work in three separate worlds, as airline operators, airport owners, and airspace managers. One difficulty is that we don't mingle very much so most of us know little about the other person's world. We all are concerned about cost and cost effectiveness. The airlines are very cost-conscious but in a different sense that the airport owner who must pay off the revenue bonds or the airspace manager who wants to reduce the annual budget for controller salaries. Some of our objectives are opposite and contrary -- the airline wants his airplane to depart and arrive without being impeded, the airspace manager wants to handle as many aircraft as possible and doesn't really mind "reasonable" delays, and the airport owner wants high use of his facilities.

The airline wants safety which he understands to be separation <u>from</u> other airplanes, the airspace manager wants safety in the sense of separation of all airplanes from each other, and the airport owner has little direct involvement although he certainly doesn't want accidents.

The airport owner has to face an angry public every day and is very much concerned to control noise while the other two parties would like to avoid limitations on their operations.

There are others looking on, too. The FAA has several worlds also, each divided and separate although not in the same ways -- the air traffic services who commonly are the airspace managers, the engineering services who develop and provide the complex facilities, and the airworthiness services who regulate the airlines and their aircraft. They too have difficulty understanding each other, sometimes with embarrassing results.

Aircraft manufacturers, who I speak for today, are more on the side of the airlines than any of the other players, although we must also make our airplanes fit the airports and navigate efficiently the terminal airspace. The difference is our time horizon--airlines are lucky to plan two years ahead, but we are looking 10 years to the future. And that's the rub, because the industry isn't organized that way. We find ourselves designing aircraft for systems which don't yet exist, whose purpose is only vaguely described, and whose operational use is not understood. No wonder we became involved in fiascos like en-route area navigation--designing systems which were never used because the operational environment turned out to be different than we had expected.

Figure 1 is a photograph of the instrument panel of our MD-11 aircraft. It's new, exciting, and still being created. See if you can remember what the panels of earlier aircraft still flying are like, and think about the differences.

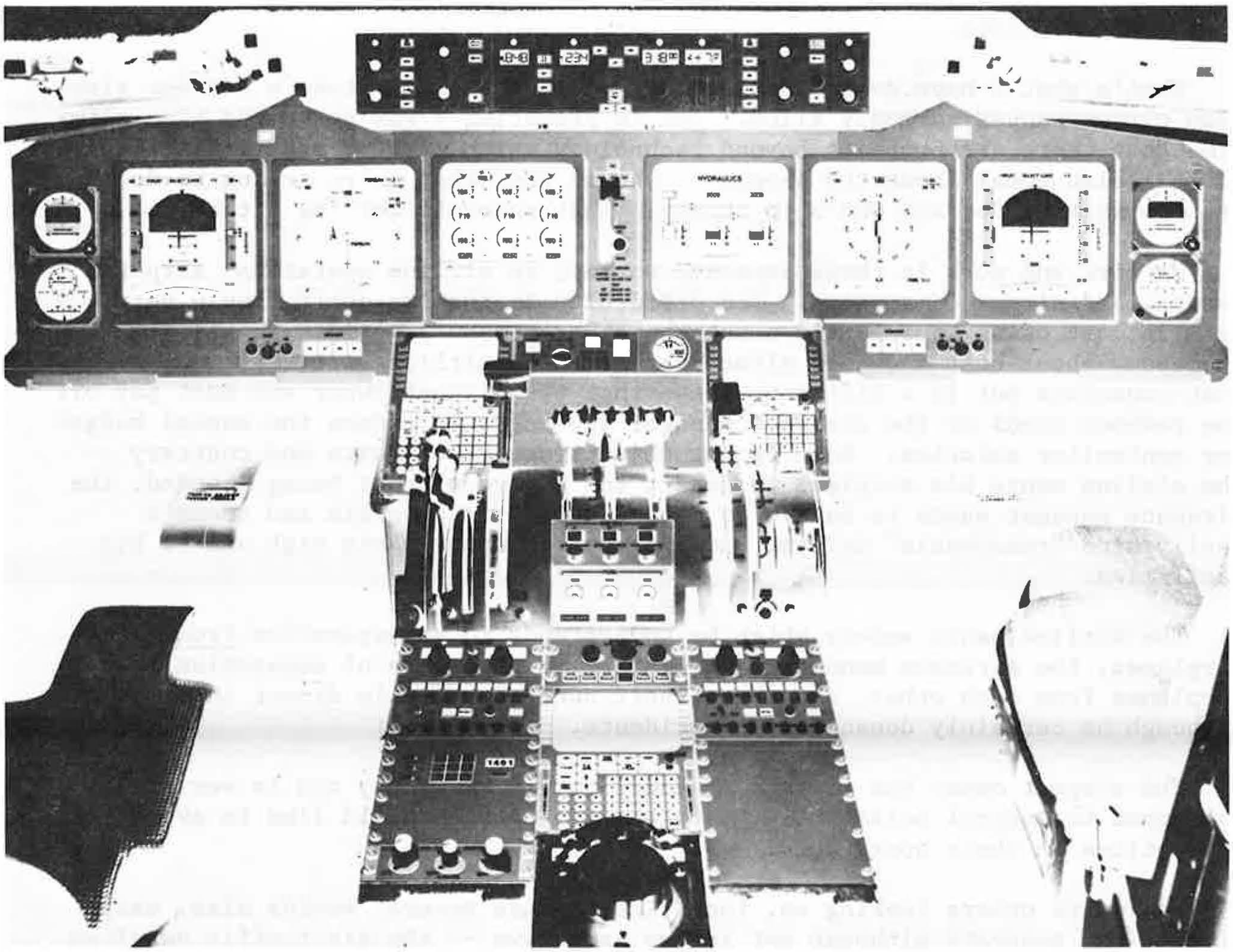

Figure 1 MD-11 Instrument Panel

The information shown on many separate instruments will be integrated to only six CRTs. A variety of formats are available to the pilots who can select exactly what they need when they need it. And there are only two pilots--at present, I don't foresee that there will be fewer but who knows. The point is not really how many pilots but how the work is divided between the machines and the pilots. The same mission can be flown effectively with either three or two pilots depending upon the kind of machines available to them.

Automation is not an end in itself. The machines should do the work suitable to machines and the people should do the people work. Some tasks may be done by either just about as well.

This approach applies both to the ATC system and to the airplanes. The scheme should not be fully automatic with the controller's and pilot's roles being "monitors"--that's the worst possible way to use people. And the arrangement shouldn't be fully manual--the people shouldn't be asked to do nit-picking details and punch keyboards in tasks requiring no judgment. What is needed is a good balance so the people and machines operate as a harmonious team, in which pilots and controllers have significant appropriate tasks performed at a moderate work load which allow a margin for abnormal, more demanding situations.

There is a lot of machinery behind those six boob-tubes, as shown in Figure 2. In fact one of the new characteristics is the high degree of integration. That's not necessarily good--everything tends to be connected to everything else. So it's necessary to provide for alternate arrangements of the parts so that needed or desired information can be displayed in several ways on several instruments from alternative power sources as the situation demands.

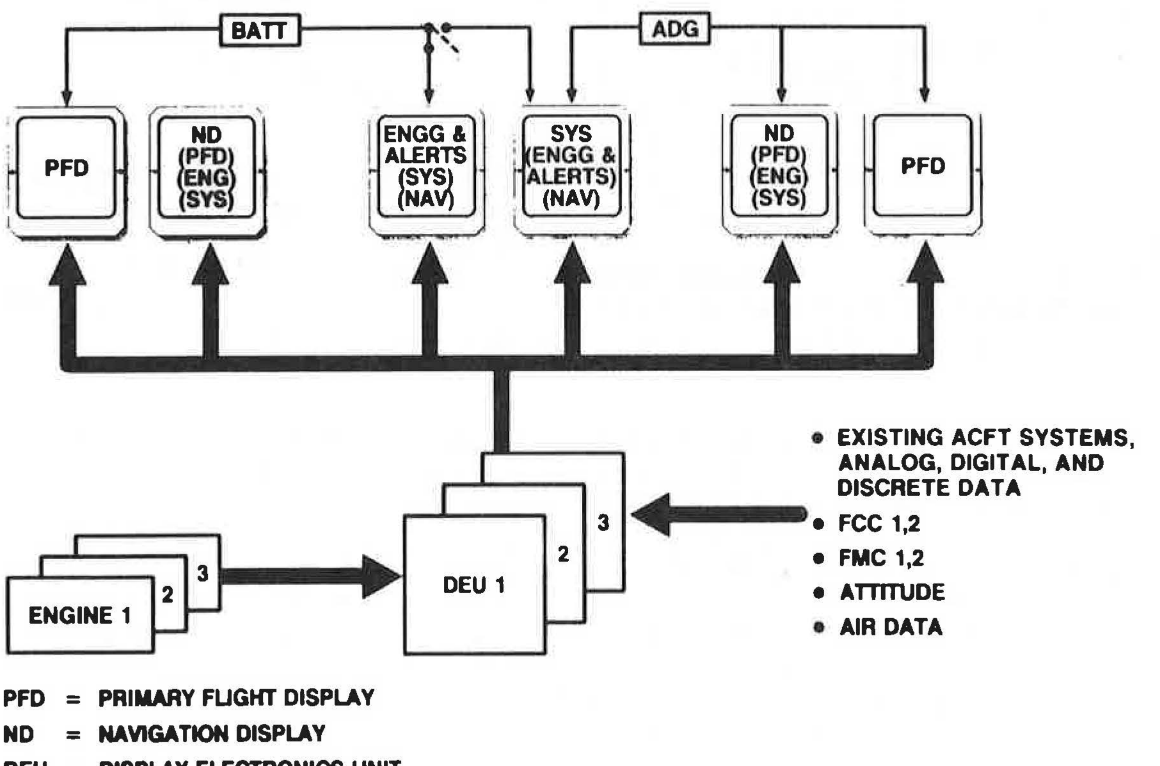

Figure 2 Electronic Instrument System

The diagram of the autoflight and flight management systems in Figure 3 shows the high degree of integration possible. Between them the three major systems process and control a lot of the operation of the aircraft. Notice the multiple sensors, the dual-dual autopilot flight control computers (FCC), the dual flight management computers (FMC), and the redundant display electronic units (DEU). The integration is good because it allows full coordination of so many interacting functions and gives the pilots new flexibility and power. It's also a problem because the airplane may be more vulnerable to abnormal conditions.

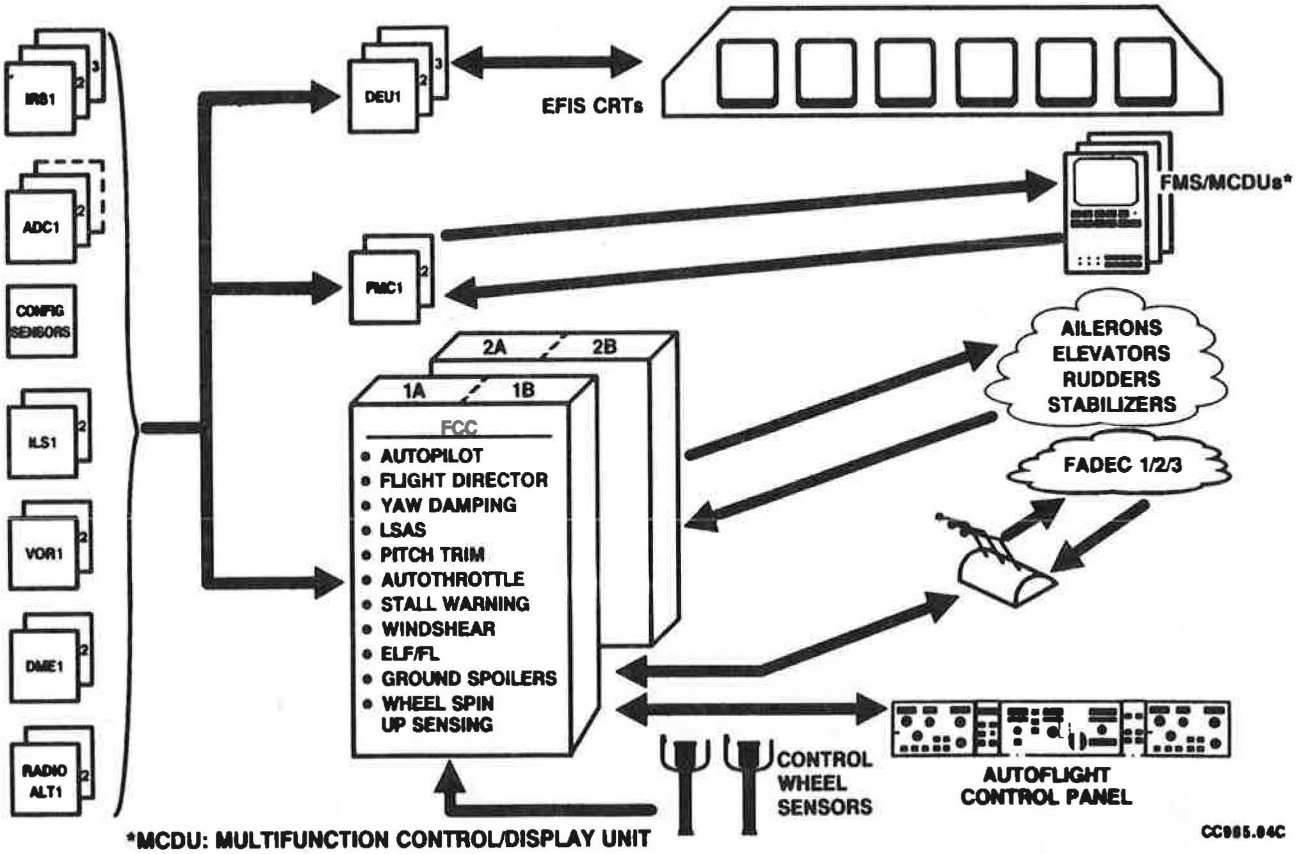

Figure 3 Autoflight and Flight Management Systems

Still another level of integration is the Aircraft Systems Controller (ASC), shown in Figure 4. In this concept, the first level action for pre-flight, normal, abnormal, and emergency procedures is taken automatically rather than by a flight engineer. This is a logical step since the first action is completedly determined by airplane design and crew training even if manually executed. The design is redundant, the airplane may be dispatched with one computer in "single mode," and manual backup is always possible. Again there is a high integration for flexibility and versatility. The potential vulnerability is anticipated and accounted for by alternative configurations with graceful degradation of functions.

Even the aerodynamic qualities become dependent upon electronics. The DC-10 achieves additional flight efficiency by reducing the size of the horizontal tail surface, as shown in Figure 5. The resulting reduction of control stability is compensated for by redundant electronic systems. This is a very modest step by comparison with some future possibilities because the aircraft is still controllable without the electronic compensation. That won't always be so.

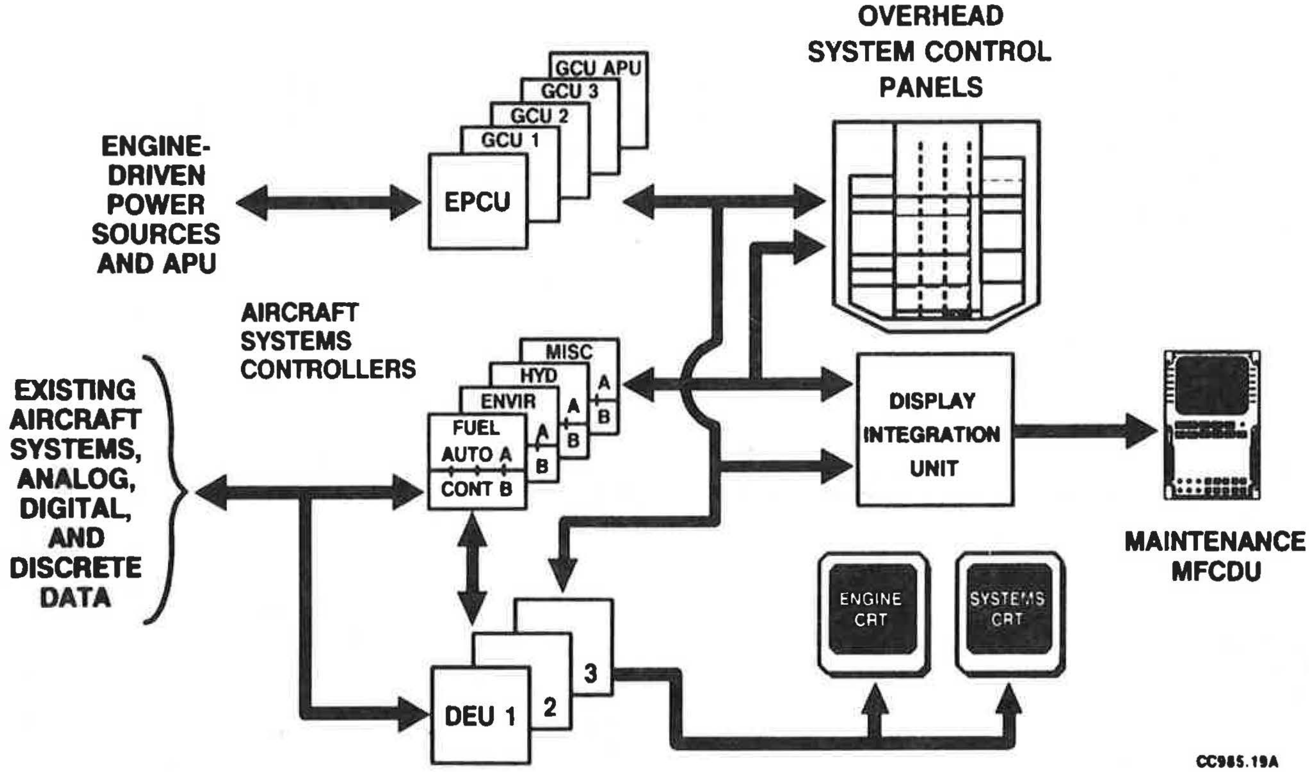

Figure 4 Aircraft Systems Controller

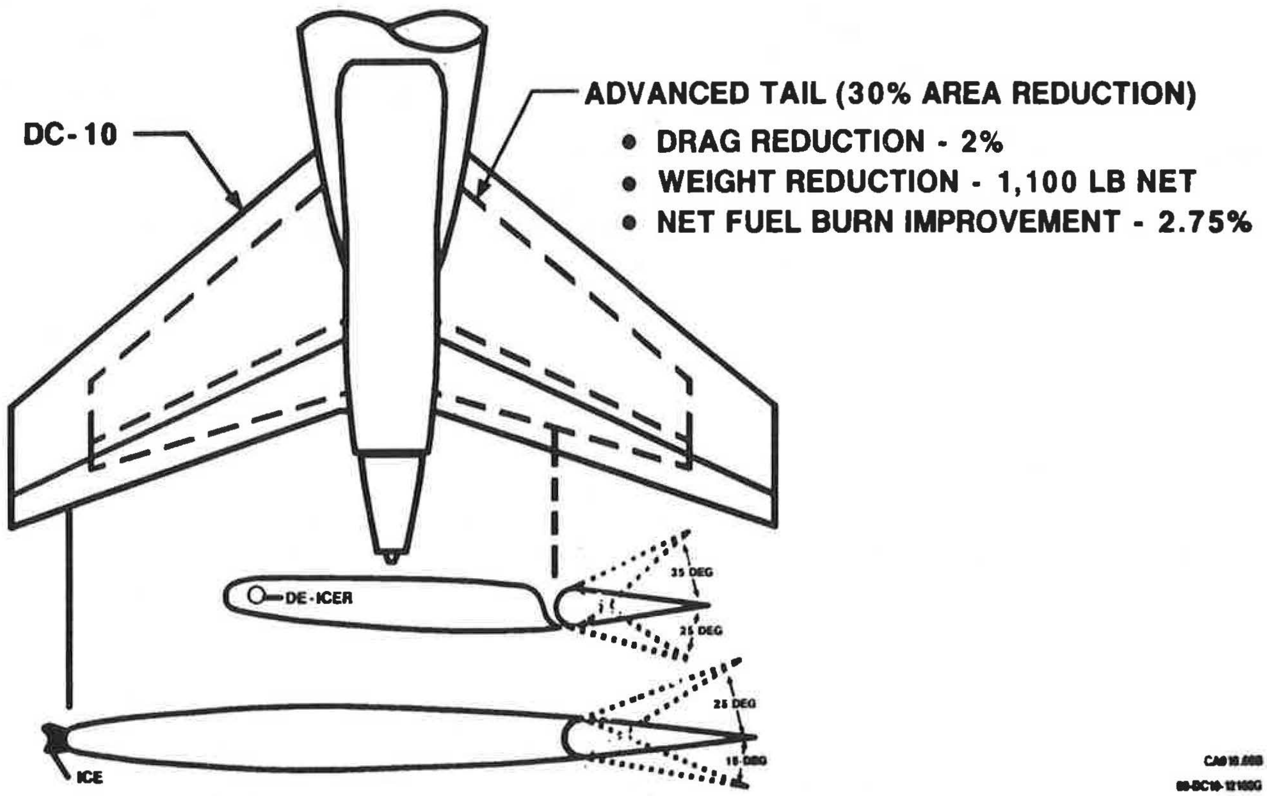

Figure 5 DC-10 Advanced-Technology Horizontal Tail

We see how functions of the aircraft are becoming more integrated so that at the limit everything connects with everything else and also that the electronic systems become more crucial to the operation of the aircraft and so more vulnerable to abnormal conditions. Our advances have begun to outpace our procedures for evaluating airworthiness and safety. Present rules evaluate particular failures and combinations of failures to ensure that no circumstances can occur that exceed the established levels of risk shown in Figure 6. But some developing systems are not suitable for evaluation by these traditional methods.

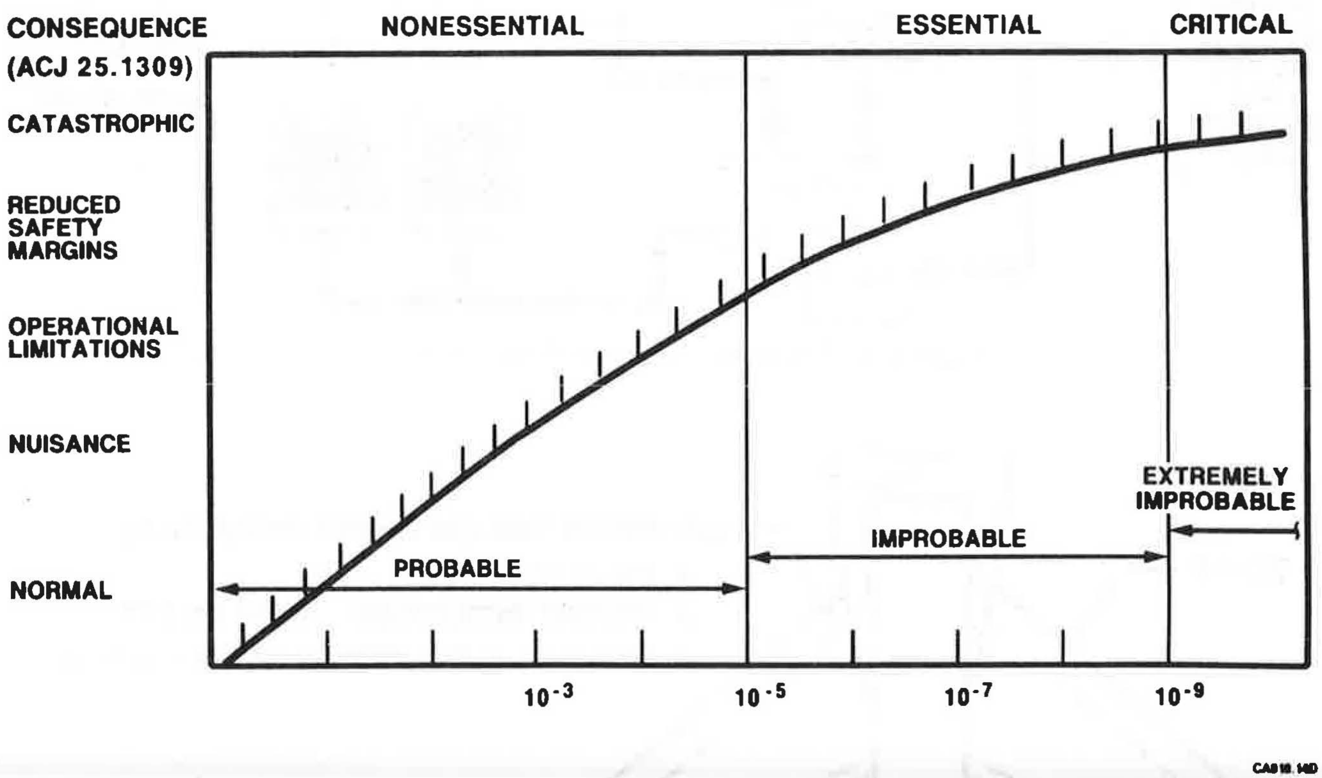

Figure 6 Airworthiness and Safety Certification Requirements

The collision avoidance system (TCAS) presently being developed is such a case. Table 1 is my summary of the FAA safety study. The FAA expects TCAS to reduce the risk of mid-air collisions, but also to introduce new risks of "induced" collisions (rarely) because of inherent methods of operation. TCAS may be found to be uncertifiable to present methods even though it clearly improves safety! New procedures are required that are just now being developed.

Another strange thing happens. TCAS should be more effective when more aircraft have altitude reporting transponders. Yet the FAA safety study predicts that the risk of induced collisions will increase because of the altimetry errors of many non-airline aircraft. Mother Nature insists that we can't deal with her piecemeal -- that we must look at the whole picture. In this case, we must improve the altimetry of aircraft when altitude reporting is added. That's a hard lesson because it's politically unpalatable to force such changes on the general aviation population.

TABLE 1 SUMMARY OF TCAS SAFETY STUDY

NUMBER OF EVENTS (PROBABILITY OF EVENT)	NMAC NEAR-MIDAIR COLLISION	INDUCED NEAR-MIDAIR COLLISION	MIDAIR COLLISION	INDUCED MIDAIR COLLISION
CURRENT 61% ALTITUDE REPORTING	80/YEAR (10^{-5}/FH)	NONE (0)	1 EVERY FIVE YEARS (2.5×10^{-8}/FR)	NONE (0)
WITH TCAS USED VMC ONLY 61% ALTITUDE REPORTING	42/YEAR (5.2×10^{-6}/FH)	0.5/YEAR (6.5×10^{-8}/FH)	1 EVERY 10 YEARS (1.3×10^{-8}/FH)	1 EVERY 800 YEARS (1.6×10^{-10}/FH)
WITH TCAS USED BOTH VMC AND IMC 61% ALTITUDE REPORTING	35/YEAR 4.3×10^{-6}/FH)	0.8/YEAR (10^{-7}/FH)	1 EVERY 12 YEARS (1.1×10^{-8}/FH)	1 EVERY 500 YEARS (2.5×10^{-10}/FH)
WITH TCAS USED BOTH VMC AND IMC 100% ALTIDUDE REPORTING	4.1/YEAR 5.1×10^{-7}/FH)	1.4/YEAR (1.7×10^{-7}/FH)	1 EVERY 98 YEARS (1.3×10^{-9}/FH)	1 EVERY 286 YEARS (4.3×10^{-10}/FH)

CA 1872.82

The lesson that everything is connected applies to airports, too. All work in capacity reveals that an airport, which consists of docks, roads, taxiways, and facilities in addition to runways and exits, is no better than its weakest link. It will do no good to increase airspace or runway capacity if the runway exits or taxiways or the terminals can't handle the increased use.

Most studies show that runway occupancy time must be reduced to match airspace improvements. The problem here is the exits rather than the runway itself. New exits are needed and new electronic and visual guidance aids will be needed.

Still another lesson awaits us. If we successfully increase capacity, won't the community noise also increase? Will the public allow us to do this?

The terminal airspace also consists of many elements that must be balanced if any overall improvement is to be realized. Longitudinal separation is the key factor, as is well known, and the wake vortex of aircraft is the basic limitation. So far as I know, the vortex is inherent in the aerodynamic process of generating lift. There is no way to reduce one without the other except with large drag penalties and increased community noise.

Table 2 contains a brief summary of some well-known improvements that are often studied. Some more lessons emerge. Those that involve minimum airplane changes also yield only small capacity improvements and in some cases increase community noise. Larger increases of capacity require major airplane changes, radical changes in procedures, and in some cases, major reconstruction of airports. There is no free lunch.

TABLE 2 AIRSPACE IMPROVEMENT

	CAPACITY IMPROVEMENT	NOISE REDUCTION	METHOD	AIRCRAFT DEVELOPMENT
UNIFORM SPEED	SMALL	INCREASE CLOSE-IN ?	PROCEDURES	UPGRADE GUIDANCE ? (CAT III)
SHORTER FINAL	SMALL	VARIABLE, POSSIBLE	PROCEDURES	UPGRADE GUIDANCE ? (CAT III)
DELAYED FLAP	SMALL	INCREASE CLOSE-IN ?	PROCEDURES	UPGRADE GUIDANCE ? (CAT III)
CURVED PATH	SMALL	VARIABLE, POSSIBLE	MLS PROCEDURES	NEW GUIDANCE
DUAL GLIDE PATH	MODERATE	VARIABLE, POSSIBLE	MLS PROCEDURES NEW ATC	NEW GUIDANCE AERODYNAMICS ?
CURVED & DUAL GLIDE PATH	MODERATE	VARIABLE, POSSIBLE	PROCEDURES ATC MLS	NEW GUIDANCE AERODYNAMICS ?
REDUCED RUNWAY SPACING	LARGE	INCREASE	NEW AIRPORT RADAR MLS	UPGRADE GUIDANCE

Some "improvements" favored by ATC specialists may not be acceptable to aircraft operators, such as the uniform speed method. There is a need for more dialogue.

The method of reducing runway spacing for independent or semi-independent operations is well known. Its application is limited because improved surveillance radars with more accuracy and faster update rates are not available and apparently will not become available according to current plans. Some synergy may be possible, though. What if we could put TCAS to beneficial use here? It's effective in detecting potential collisions and updates itself once per second.

Another caveat is needed. If we succeed in improving the use of parallel runways, won't community noise increase? Will the public let us do that?

At Douglas, we have been investigating the use of MLS to allow curved path operations. We took visual procedures as our model for IMC guidance and constructed the path concepts shown in Figure 7. This goal if realized would

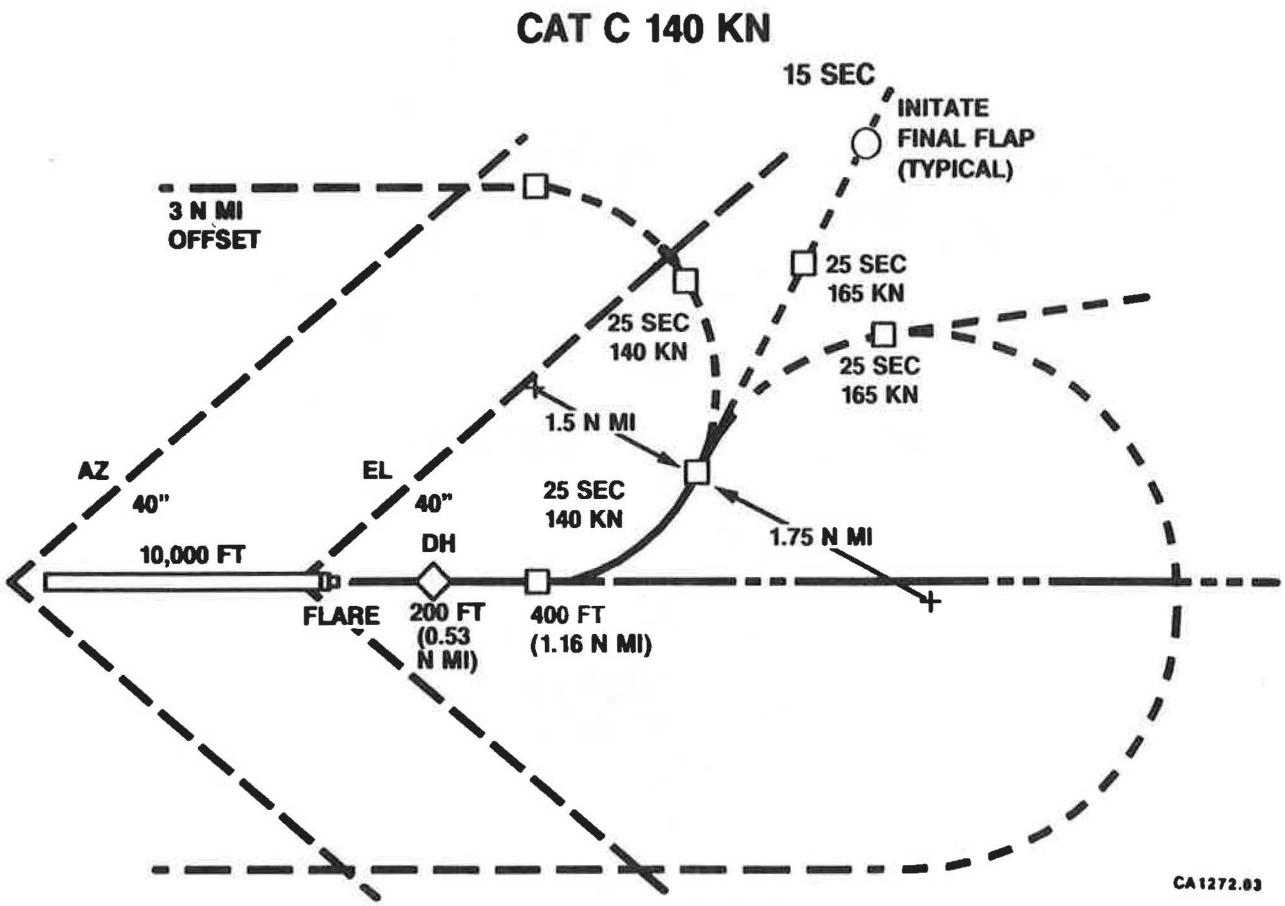

Figure 7 MLS Path Concept

result in a combination of curved paths, delayed flap and short final methods. Our results are favorable so far.

However, we are encountering institutional barriers. That section of the FAA responsible for TERPS and hence for ILS terminal procedures probably will issue the guidelines for MLS curved paths shown in Figure 8. The procedures are notable in being similar to ILS IMC operations (rather than visual operations). The result is simply not useful--existing en-route area navigation equipment could do this without need for MLS! Many observers doubt that the really useful applications of MLS will ever be developed--much less approved and adopted--because of these closed institutional systems.

My conclusion is this. Technical methods are available or can be developed to resolve many foreseeable problems. The real limitations are those associated with all large-scale systems. We don't understand what we want and need to do and consequently don't understand what the real requirements are. We extrapolate current experience, traditional procedures, and current problems blindly and place unnecessary limitations upon ourselves. We devise highly integrated solutions in which everything is connected to everything else, in which all parts are critical to the proper function of the whole system, and that require revolutionary changes when only step-by-step evolution is possible.

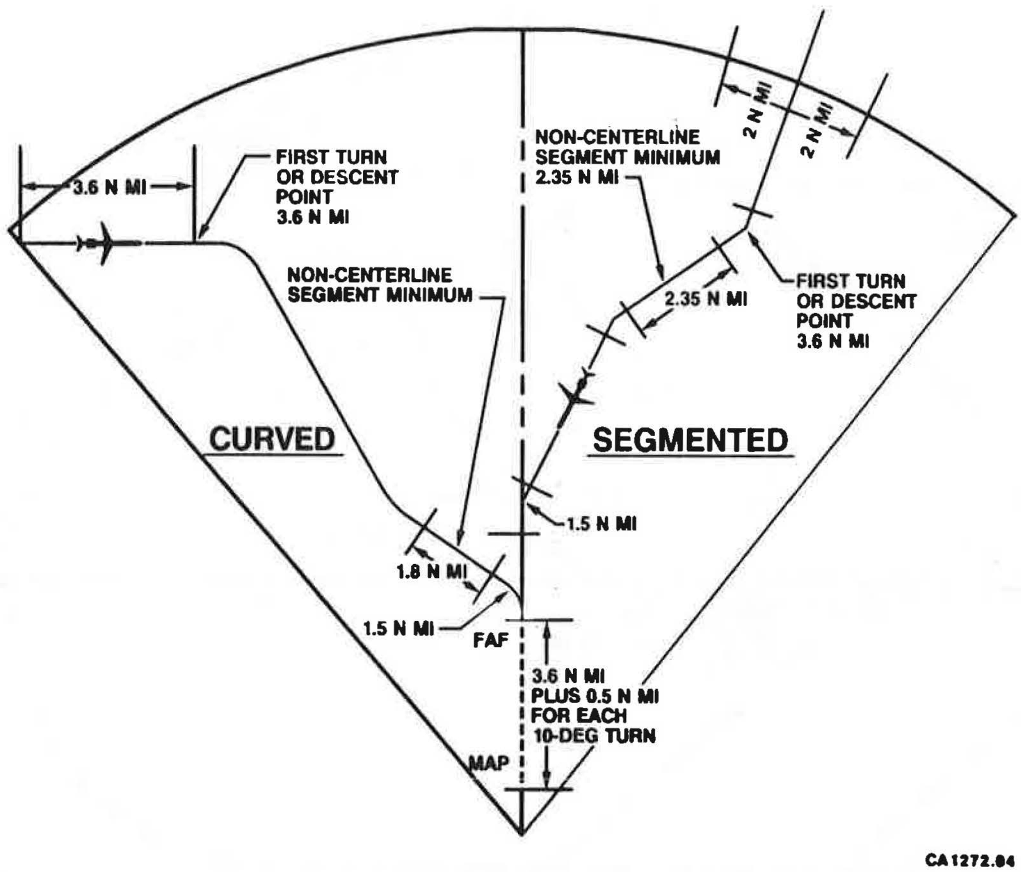

Figure 8 FAA MLS Path Concept

We are unable to overcome the rigidity of our institutions and organizations. We don't talk to each other enough and we don't understand each other's problems.

Things are in the saddle,
and ride mankind.

There are two laws discrete,
Not reconciled--
Law for man, and law for things,
The last builds town and fleet,
But it runs wild,
And doth the man unking.

The poem was written by Ralph Waldo Emerson in another time of rapid change. I think the problem is not with the things, but with ourselves. We can regain control if we get our act together.