propeller/fan blades, it had a direct turbine drive. The GE36 demonstrated a 15% fuel burn reduction, compared to contemporary turbofans [2], based on some 281 hours of flight testing. Faced with a market where fuel prices were dropping, the program was ended in 1989. In the words of a GE manager, “The signs were there the year before, that at 65 cents per gallon, the fuel price was too low to justify the UDF. If fuel were at a buck or so a gallon they’d be clamoring.”

In this new century, as fuel prices rose dramatically in the early 2000s, the price of a barrel of oil continues to be a deciding factor for the fate of open rotor engines. Added to this, is the consideration of climate change and reduction of greenhouse gas emissions by aircraft engines. Recent development efforts include Rolls-Royce, which has a prototype gear-driven open rotor engine, the RB3011, under development and aimed at a market entry by 2020. In France, Safran Aircraft Engines has completed ground testing of an open rotor engine, as part of the European Clean Sky 2 research program. The Safran open rotor engine has a gearbox, with carbon fiber 15 ft diameter propeller/fan blades. Recently plans for flight testing the engine on an Airbus aircraft have been halted, with reports Airbus interest in the fuel-saving engine have been put on hold.

OPEN ROTOR CHALLENGES

Van Zante [2] has outlined three technical challenges that remain to be addressed for successful open rotor propulsion:

1. Noise is a problem. Additional noise reduction beyond what has been accomplished to date, is necessary.
2. Airframe integration, with open rotor propeller/fan blade diameters of 12-15 ft. is a challenge, for both wing and tail mounting locations.
3. Protecting passengers in the event of a propeller/fan blade failure (e.g., caused by a bird strike) needs to be addressed.

Of course, underlying everything, is the price of a barrel of oil!

REFERENCES

Aviation, Gas Turbines and the ‘Three Worlds’

During my 38 year career at GE Aircraft Engines, I was privileged to have had the opportunity to work on a variety of projects ranging from advanced technology demonstrator engines, military bomber and fighter engines and commercial engines for many of the world’s commercial airplanes. It doesn’t get better than that for a person who has been fascinated with airplanes and aviation for his entire life. In addition to that, I worked for a good company which considered safety and reliability as being their underlying value. Then on July 19, 1989, a DC10-10 powered by CF6-6 engines crashed in Sioux City Iowa killing 111 passengers. At the time of the accident, I was the engineering manager responsible for the CF6 engine product line.

The post-accident investigation revealed that the event was initiated by the failure of the fan disc which was at the front of the engine mounted in the tail of the three engine DC10-10. That failure released high energy debris which breached all three hydraulic lines running through the horizontal stabilizer of the airplane. That loss of hydraulic pressure made the aircraft essentially uncontrollable and, in spite of heroic efforts by the crew, the airplane crash landed in Sioux City.

That accident was a life changing event for many people especially the victims and their families. However, what I didn’t expect was that it was life changing for me as well. Why? Because a number of years before the accident, I was working on a problem which was eventually proven to have been the initiator of the event. Not only that, in retrospect, I concluded that I had made a decision which, had it been different, may have prevented the accident. I was devastated!
For a number of years following the accident, I tried to figure out why it happened and why a good company and people with good intentions could have made mistakes which led up to this tragedy. I was particularly focused on what I knew and what I did preceding the event. I drew a number of conclusions and, when I became Chief Engineer, instituted a company policy based on those conclusions addressing how we made product safety decisions. That policy is essentially the same as the one GE Aviation uses today.

Following my retirement in 2002, I watched as a number of really big/bad events happened which involved large organizations. Specifically those events were the BP oil spill into the Gulf of Mexico and the GM ignition switch problem. They not only involved a loss of life but had huge financial and reputation consequences for BP and GM. I immediately looked into them and had the thought that, if those organizations had the benefit of what I had concluded about the Sioux City DC10 event, those events might have been prevented.

Then two other huge events involving large organizations happened. They were the Flint Michigan lead in the water and the VW Diesel emissions cheating events. But these events were very different for Sioux City, BP, or GM. Why? Because the involved unethical behavior inside the organization. That was an eye-opener for me. I could not believe that the organizations and the people in them could resort to behavior that was so egregious. That was especially true of the Flint Michigan event where the people and children of the City of Flint were supplied with lead tainted water.

All of this led me up to developing a set of “factors” which I believe influence the way people in large organizations make decisions. They are:

- Values
- Goals
- Culture
- Measurements
- Perception of Risk
- Organizational Complexity

Based on these “influence factors” I developed a set of principles which I believe give guidance to those in organizations which are involved in projects which might result in disastrous consequences for the users and the creators of the products involved. These principles are:

- Clearly communicate the values of the enterprise
- Build and nurture the “right” culture
- Always get diverse input when making critical decisions
- Trust but Verify
- The “logo” is responsible so the “logo” should make the decision
- Define individual roles and responsibilities

Well, how does all this relate to aviation, gas turbines, and the “three worlds”? First of all, I believe that the aviation environment (and especially commercial aviation) is different in that the lives of the passengers and crew are immediately and directly linked to the proper functioning of both the aircraft and the engines powering them. The expectation of the “outside world” (the passengers, the future traveler, the governments, the media, the regulators, etc.) is absolute. A safe flight is assumed! The corporation (the second “world” – I use the term “logo”) will be held responsible for their actions both technically and ethically! But, the organization is made up of people! You as members of the organization dictate what the organization does. This then brings up the “third world”. You are members of, not only the “corporate world”, but of the “personal world”. I can tell you from personal experience that, should you be involved in a catastrophic event and if you are a responsible and moral individual, you will judge yourself on what you knew and what you did prior to its happening.

Let me leave you with these thoughts. The aviation business is the “Yankee Stadium” of businesses. It is the most responsible, most technically advanced, and involves huge amounts of money. It is only a place where the best, the brightest, and the most responsible people ought to be. It is also a place where there are risks and risks have to be managed. That means decisions have to be made. Making those decisions is never easy. If you are lucky enough to be involved in this business, always do the best job that you can. That is what is expected of all of us. And, should the “doomsday event” occur, that is what you will have expected of yourself.

If you would like to read more about the topic of making decisions in large organizations, I have a book out on Amazon called What Did We Know? What Did We Do? [1]

Advanced Manufacturing is changing the ways that many companies do business, as it has been proven to reduce lead time and cost while enhancing performance and innovation. This 2-day symposium brings together engineers, designers, researchers, repair professionals and business leaders at companies that design, manufacture, repair and own gas turbines to:

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- Network with experts in advanced manufacturing for gas turbines.

**YOUNG ENGINEER TURBO EXPO PARTICIPATION AWARD**

The ASME Gas Turbine Segment Young Engineer Turbo Expo Participation Award (YETEP) is intended for young engineers at companies, in government service, or engineering undergraduate or graduate students in the gas turbine or related fields to obtain travel funding to attend ASME Turbo Expo to present a paper which they have authored or co-authored.

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**February 1, 2019**

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The Student Advisory Committee (SAC) represents the interest of the students who attend Turbo Expo and serves as a student-specific liaison to the Gas Turbine Segment Leadership Team. The Committee will engage students by creating student-oriented programs at ASME Turbo Expo, such as poster presentation, tutorial sessions and activities that facilitate student interaction and networking with turbomachinery professionals.

For more information on the Gas Turbine Segment Honors and Awards Opportunities, visit [https://community.asme.org/international_gas_turbine_institute_igti/wiki/4029.honors-and-awards.aspx](https://community.asme.org/international_gas_turbine_institute_igti/wiki/4029.honors-and-awards.aspx)