Revealed Preference Survey for Aviation Safety Research and Development

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Overview

One important method in which the FAA fulfills its mission to enhance and promote aviation safety is to undertake, or sponsor, safety-related research and development (R&D). As such, the FAA created the Airworthiness Assurance Center of Excellence (AACE) to contribute significantly toward accident rate reduction. While AACE has a sizable budget to carry out, or sponsor research related to safety, it is not clear that the R&D agenda is as responsive to industry needs as it could be.

Objectives and Methodology

The goal of this study is to focus the safety R&D agenda to be as responsive to industry needs as is possible given the limitations properly imposed through the necessity to pursue R&D that meets the regulatory requirements of the FAA. In order to meet this objective, research staff at AACE member schools (primarily the Transportation Center at Northwestern University) conducted a series of 43 "revealed preference" interviews with senior executives of air carriers, major general aviation companies and their principal suppliers. The interview was designed to solicit the views and preferences on issues in the area of aviation safety most relevant to the industry and the respondent's company. Both prompted and non-prompted questions were used to reveal such preferences for airworthiness assurance R&D. As a result, a "menu" of research priorities revealed to be most important to this diverse group of FAA constituents is presented. It should be noted that while the primary focus of the interview instrument (Appendix B) was on safety R&D, opportunity was given for those interviewed to indicate their preferences regarding other R&D relevant to civil aviation.

Summary of Results – Non-Prompted Research Priorities

Table 1 below summarizes those safety-related areas of greatest interest or concern that were mentioned on a non-prompted basis.

TABLE 1: Non-Prompted Research Priorities

Issues	Count	Rank
Air Traffic Management (ATM)	17	1
Advanced Materials	7	2
Maintenance Training	6	3
Human Factors	5	4
Fire, Smoke, Toxicity of Materials	3	5 (tie)
Maintenance Errors	3	5 (tie)

Air Traffic Management (ATM)

More than one-third of all respondents mentioned, on a non-prompted basis, that the government should make investment in research addressing problems related to ATM in the U.S. a high priority. This issue is clearly of great concern to many, and some of the responses were particularly passionate. Of primary concern was the ATM system's ability to adapt to an increasing number of aircraft movements and to deploy necessary—often-revolutionary—technology. In particular, it was expressed that airspace needs to be managed more efficiently, and the reliability and accuracy of ATM systems need to be improved. Thus, there was both a safety and an efficiency aspect to the ATM concerns identified.

Advanced Materials

Seven respondents urged R&D related to materials as used in aircraft and/or propulsion systems. The biggest concern expressed had to do with the use of composite materials in primary aircraft structures, with several respondents stating that they believe the U.S. is lagging in knowledge in this area, particularly as it relates to MRO activities and the long-term airworthiness of these materials. In addition, some respondents indicated concern that FAA personnel involved in the certification process of new materials and construction methods, as well as in the monitoring and regulation of inspection procedures related to new materials and composites, do not have the requisite knowledge.

Maintenance Training

The need to make training more effective, particularly maintenance training and education, was underscored. Increasing skill requirements as a result of the growing complexity of aircraft and

engines was cited as the primary reason that maintenance training needs to be enhanced. Thus, training is becoming more vital as the workplace and technology become more complex.

Human Factors

Respondents also indicated strong interest in government-funded research into human factors issues. In particular, respondents cited a desire to better understand how humans interface with machines, given the increasing technical complexity of aircraft and their sub-components in order to make products safer. Concerns related both to MRO and flying (i.e., pilots).

Fire, Smoke, and Toxicity of Aircraft Materials

Several respondents showed concern about fire, smoke and toxicity of aircraft materials and the need to perform more research to understand the behavior and to improve upon these materials, as well as ensure that appropriate regulations are in place.

Maintenance Errors

Several respondents also mentioned a concern about maintenance errors and their potential to degrade safety. In particular, a need for better trained people and better ways to catch human mistakes was underscored. The comments here appear to tie in very closely with those made about the need for more human factors research and improved maintenance training and education.

Summary of Results – Prompted Research Priorities

Table 2 below summarizes the affirmative response rate for those safety-related areas where the area was prompted (i.e., suggested) to each respondent.

TABLE 2: Prompted Research Priorities

Issue	Affirmative Response	Rank	Issue	Affirmative Response	Rank
Aircraft Maintenance	60%	1 (tie)	Corrosion Control	49%	10
Aircraft Repair / Overhaul	60%	1 (tie)	AMT Standards and Practices	47%	11
FAA Inspector Performance	60%	1 (tie)	Engine MRO	44%	12
Regulatory Processes	60%	1 (tie)	Engine Life Extension	40%	13
Aircraft Inspection	58%	5 (tie)	Supply of MRO Labor	37%	14
FAA Inspector Training	58%	5 (tie)	Crashworthiness	30%	15 (tie)
Polymeric Composites	58%	5 (tie)	Landing Gear	30%	15 (tie)
Aircraft Modifications	56%	8	Ceramic Matrix Composites	28%	17
Engine Condition Data	51%	9	High Temp. Aluminum Alloys	26%	18

The top four research priorities the prompted responses elicited are briefly summarized below.

Aircraft Maintenance

Respondents holding that the quality of aircraft maintenance is not adequate cited this factor as a top concern. Numerous respondents suggested that the main problem is a current lack of effective training for AMTs, coupled with the growing complexity of new aircraft. Some respondents also suggested the need for systems to be developed to replace some of the people-based aircraft inspections with "machines monitoring machines."

Aircraft Repair / Overhaul

This factor was also cited as a top concern by respondents for many of the same reasons that the quality of aircraft maintenance is considered by many to be inadequate. However, some respondents, who did not believe this was of concern, suggested that inadequate aircraft repair and overhaul is really an enforcement issue for the FAA, not a safety R&D issue.

FAA Inspector Performance

Numerous comments here suggested that inspector training and performance are not adequate, as it is believed that inspectors do not receive enough training and must spend too much time on paper work.

Regulatory Processes

Finally, 'regulatory processes' was cited as a top concern as many respondents believe that government (FAA) regulation imposes many burdens on the industry that are seen as government "interference" without clear safety benefits. Such burdens include onerous paper work and data that needs to be supplied to the FAA. In addition, some respondents argued that there is not a true regulatory mechanism in place for determining acceptable safety standards.

1. Introduction

1.1. Background and Motivation

The Airworthiness Assurance Center of Excellence (AACE) represents an important departure for the conduct of airworthiness assurance safety-related research in the United States. This new, coordinated effort to join many parties together in a cooperative research venture has the potential to meet the needs of industry more precisely as they arise, and to do so in a more timely manner.

To determine what appropriate industry constituents of the Federal Aviation Administration (FAA) and AACE see as research endeavors relevant to their interests, AACE has conducted a series of "revealed preference" interviews. They are designed to determine respondents' preferences regarding safety, or "airworthiness assurance," research and development (R&D) efforts and to gauge their interest in supporting such research with resources to match those of the FAA.

1.2. Objectives

In the context of AACE's *Five-Year Plan*, the final results of the industry revealed preference interview initiative help establish the menu and priorities with which at least a substantial portion of the research is most appropriately undertaken. Given the shared goal of the FAA and AACE to enhance civil aviation safety, this is accomplished through a more focused R&D agenda.

1.3. Methodology of Study

Staff at the Northwestern University Transportation Center (NUTC) designed the interview instrument and analysis upon which this report is based. Interview instrument design, interviewer preparation and interview format are discussed in separate sections below.

1.3.1 Interview Instrument Design

Questionnaire Structure

A "Revealed Preference" study is designed to accomplish just what the name implies: to determine the true preferences of the persons interviewed with respect to the subject the

interview seeks to explore. In the present case, the prime focus was on FAA-sponsored safety-related R&D. Thus, senior executives from a broad spectrum of the civil aviation community were interviewed in such a way as to enable the researchers to determine their preferences as to how those FAA R&D resources available for deployment beyond projects required to meet the FAA's own unique needs can best be allocated.

The technique requires an in-depth interview and, because of this, a relatively small number of interviews – a total of 43 – were completed for this study. (See Appendix A, a list of those interviewed.) As a result of the rather small sample size, the data do not have statistical validity. However, the technique does allow for the gathering of important qualitative data from key constituents of the FAA, and provides substantial insight into those areas of safety-related (and some other) research activities that are most important to these constituents.

More specifically, the survey questionnaire consists of 26 total questions. The first set of questions are designed (1) to collect background information about respondents and respondents' firms that can be used as the basis of future segmentation, and (2) to enable respondents to set aside biases related to safety research before proceeding to the second set of questions. The latter group of questions serves as the basis for the majority of the survey's findings as it deals specifically with the relevant aspects of the research agenda. (See Appendix B, the revealed reference questionnaire.)

Prompted and Non-Prompted Responses

The design of the interview instrument explicitly recognized all interests and issues could not be foreseen. Furthermore, it was acknowledged that even for those issues that could be pre-identified, the precise form and nature of responses was impossible to predict. Therefore, the second portion of the interview instrument was designed to allow for both prompted and non-prompted responses. Whereas the prompted questions allow for a measurement of certain issues across all respondents, a considerable portion of the findings and understanding of the issues is necessarily derived from respondents' non-prompted responses. There appears no basis for giving greater weight to one sort of response than the other.

Interview Outline

Following is the outline of the survey questionnaire.

I. *Background and Career*

1) Career
2) Education
3) Present Position

II. *R&D Projects and Programs – Past*

4) R&D Project List
5) R&D Characteristics

III. *Characteristics of R&D Projects and Programs*

6) Multi-Firm R&D
7) Cost-Benefit Forecasting
8) Labor Unions
9) Licensure Standards
10) FAA Involvement in R&D
11) Industry Sharing
12) Safety Value
13) Patents and STCs
14) Supplier Research
15) Customer Research
16) International Research

IV. *Policy Issues*

17) Public R&D Investment
18) Issues in the Company

V. *"Airworthiness Assurance"*

19) Issues in Airworthiness
20) Issues: Data
21) Issues: Other

VI. *R&D Projects and Programs – Present and Future*

22) R&D by Company
23) General Industry Issues

24) Top Research Priorities

25) Government Policy

26) Final Comments

1.3.2 Interview Preparation

Individuals from each of the AACE member school interview teams were hosted by the NUTC team for a one-day familiarization session on February 11, 1998. During the meeting, they were shown videotape of the first interview conducted by the NUTC. Subsequently, the interview instrument was discussed question by question with the objective of having a similar interview technique used by each interviewer.

1.3.3 Interview Protocol

Interviews were conducted at respondents' sites by two-member teams drawn from the AACE member schools, with the bulk of the interviews being performed by staff from NUTC. Each team was composed of an interviewer and a recorder. Interviewers were responsible for establishing a relaxed atmosphere in part by assuring respondents of response anonymity in the data and for the actual conduct of the interview. Recorders sought to capture as much of the information and data provided by respondents as possible. In particular, recorders were instructed to be equally attentive to prompted and non-prompted responses.

2. Respondent Profile

A total of 43 completed interview instruments have been analyzed. The goal was to gather information from a broad mix of constituents in the aviation value chain in order to generate as complete of a picture as possible as to overall industry interests and a sense of priorities for safety-related R&D. Aircraft operators, airframe and engine manufacturers, component manufacturers, and others such as maintenance, repair and overhaul (MRO) facilities and other aviation-related service providers were included in the interview program. Respondent composition is detailed in the table below.

TABLE 2.1: Respondent Profile

Respondent Type	Count	Percentage of Total
Aircraft Operators	18	42%
Airframe OEMs	8	19%
Component Manufacturers	7	16%
Engine Manufacturers	4	9%
Other	6	14%
Total	43	100%

Respondents chosen were those with senior executive responsibilities in the areas of maintenance, engineering, and / or safety, as these individuals are most likely to be involved with, and have an understanding of, safety-related R&D. (Also, they are likely to have authority to commit resources to joint FAA-industry R&D projects.) This highly educated group consisted of 26 individuals that had attained a master's level degree or higher, typically in an engineering or business administration discipline. In addition, all but one respondent indicated that they had specific responsibilities related to aviation safety within their organizations.

3. Characteristics of R&D Projects and Programs

3.1. R&D Practices and Policy

Respondents were asked numerous questions about R&D practices and policy in order to understand better the level and type of R&D that is undertaken at the respondent's firm, if any. This provides context for later questions about respondent's opinions as to the types of safety-related R&D seen as most relevant and useful to this diverse group of FAA constituents. Following is a summary of responses.

3.1.1 Multi-Firm R&D

When asked whether their firm has undertaken any multi-firm R&D projects or programs, 72% of respondents answered affirmatively. Approximately 53% indicated that such R&D has sometimes been undertaken with the involvement of competitors, while 77% indicated that such R&D had been undertaken with the involvement of suppliers. Only 40% of respondents indicated that any R&D projects or programs had ever been undertaken with customers. Table 3.1 below summarizes these results.

TABLE 3.1: Multi-Firm R&D

	Affirmative Responses	
Issue	**Count**	**Percentage**
Multi-Firm R&D	31	72%
R&D with Competitors	23	53%
R&D with Suppliers	33	77%
R&D with Customers	17	40%

3.1.2 Ex-Ante Evaluation of R&D Projects and Programs

Respondents were asked whether they explicitly forecast expected benefits, costs, and return-on-investment (ROI) of the project or program before beginning such R&D. Approximately 70%, 65%, and 63% of respondents indicated that they explicitly forecast benefits, costs and ROI, respectively. A lower percentage (53%) indicated that they explicitly compare or rate R&D projects or programs against each other. Additional factors that were mentioned by respondents

as being used in selecting projects or programs primarily include customer satisfaction and contributions to safety. Table 3.2 below summarizes these results.

TABLE 3.2: Forecasting of R&D Results

	Affirmative Responses	
Issue	**Count**	**Percentage**
Forecast Benefits	30	70%
Forecast Costs	28	65%
Forecast Expected ROI	27	63%
Compare or Rate Projects	23	53%

3.1.3 Ex-Post Evaluation of R&D Projects and Programs

After completing an R&D project or program, 60% of respondents indicated that their firm evaluates the R&D by comparing actual vs. expected costs, while 51% indicated that they compare actual vs. expected benefits. Roughly 49% indicated that they consider the value of other desirable but unexpected outcomes. Table 3.3 below summarizes these results.

TABLE 3.3: Evaluation of R&D Results

	Affirmative Responses	
Issue	**Count**	**Percentage**
Actual vs. Expected Costs	26	60%
Actual vs. Expected Benefits	22	51%
Other Desirable Outcomes	21	49%

3.1.4 Other Considerations

Respondents were also asked whether labor unions were consulted or considered in setting R&D agendas or goals or during R&D design or conduct. Only 21% of respondents answered affirmatively. They were also asked whether licensure standards or aviation maintenance technician (AMT) training is considered, or whether they should be. Roughly 53% of respondents answered affirmatively.

3.2. Gauging Firm Interest in Airworthiness Assurance R&D

The next set of questions was used to gauge firm interest in the conduct of airworthiness assurance R&D. Following is a summary of responses.

3.2.1 FAA Involvement in Supporting R&D Related to Safety

Respondents were asked whether they welcome FAA interest in supporting R&D related to airworthiness assurance. The overwhelming majority of respondents, 88%, replied affirmatively. Numerous respondents indicated that this is an appropriate area for FAA because the agency can bring special expertise to R&D that can enhance safety and benefit the entire industry. Some respondents suggested that a better partnership between the FAA and industry would be particularly useful and may lead to a lessening of regulation.

However, even among those that answered affirmatively, many respondents indicated that there should be limits on FAA involvement in R&D. Some indicated that FAA involvement is "too constraining," while some believe that the FAA has differing objectives from industry. One respondent indicated that the FAA is too slow to market, and runs big, complicated projects that take too long to complete. This particular respondent stated that the FAA should be involved in such R&D, but should not be "the quarterback." Numerous respondents also suggested that NASA, either instead of the FAA or along with the FAA, should be primarily involved in such R&D.

Respondents were then asked if the government (e.g., FAA) contributes resources to such efforts alongside industry, does it matter if their competitors were also involved? Only 26% answered affirmatively, echoing earlier comments that the FAA and its industry constituents should partner together in such areas of R&D to benefit the overall industry. Finally, when asked whether the government (e.g., FAA) should participate in setting R&D agendas where the government has supplied substantial resources, 74% answered affirmatively. Table 3.4 below summarizes these results.

TABLE 3.4: Firm Interest in Airworthiness Assurance R&D

	Affirmative Responses	
Issue	**Count**	**Percentage**
Welcome FAA Support	38	88%
Matters if Competitors Involved	11	26%
FAA Participate in Setting Agenda	32	74%

3.2.2 R&D Results and Competition

Respondents were asked whether their firm's R&D results are shared with the industry, and under what conditions. Roughly 60% of respondents answered affirmatively, and stated that if they share R&D results, it is typically shared through technical papers. Most respondents, however, added the caveat that they only share R&D results that are sufficiently generic and then only if it will not jeopardize their firm's competitive advantage.

When asked whether it matters whether the R&D is intended to reduce costs rather than provide a "better" product (or service), 57% responded that it did not matter. When asked if safety-related R&D results are seen as a competitive issue, 40% responded affirmatively, while 49% responded that they did not consider safety-related R&D results as a competitive issue. (The remaining 11% made no response.) Table 3.5 below summarizes these results.

TABLE 3.5: Sharing of R&D Results

	Affirmative Responses	
Issue	**Count**	**Percentage**
Firm's R&D Results Shared with Industry	26	60%
Matters if Reduces Cost vs. "Better Product"	16	37%
Safety R&D Results a Competitive Issue	17	40%

3.2.3 Safety Enhancements and Civil Aviation

When asked whether safety enhancements are always "good" for civil aviation, only 42% of respondents answered affirmatively, while 49% answered "no." (The remaining 9% had no response.) While some respondents believed that safety enhancements are "absolutely" good for

civil aviation, numerous respondents suggested that there is a tradeoff in the cost of such safety enhancements and their benefits. Interestingly, numerous respondents pointed to a similar example – federally mandated 16-G aircraft seats – as an example of a safety enhancement in which the benefits are marginal at best, yet come with an enormous cost burden to aircraft manufacturers and operators. Another respondent stated that often, when new regulations are developed in an attempt to enhance safety, the actual result is an increase in cost and complexity without a commensurate – or even any – safety benefit. Thus, overall, the respondents clearly questioned whether safety enhancements are always "good" for civil aviation.

When asked whether R&D results that enhance civil aviation safety should be made known regardless of the source of such R&D results, 67% responded affirmatively, while only 21% responded "no." About 60% of industry respondents believe their views on this subject are shared widely by others in similar industry positions.

TABLE 3.6: Safety Enhancements and Civil Aviation

	Affirmative Responses	
Issue	**Count**	**Percentage**
Safety Enhancements Always "Good" for Aviation	18	42%
R&D Results Made Known Regardless of Source	29	67%
Believe that Views are Shared Widely by Others	26	60%

3.2.4 R&D Undertaken with Suppliers, Customers and Non-U.S. Entities

When asked if the respondent's *suppliers* undertake or sponsor R&D that supports their firm's interests and which also relates to "airworthiness assurance," 81% responded affirmatively, while 60% indicated that they have some influence on the projects thus undertaken. When asked if the respondent's *customers* undertake or sponsor R&D that enhances their own firm's ability to perform and which relates to "airworthiness assurance," only 40% responded affirmatively. Here, 30% indicated they have some influence on the projects undertaken. When asked if their firms participate in joint R&D efforts related to "airworthiness assurance" with any non-U.S. entities, 72% responded affirmatively. However, only 26% of respondents indicated that there is anyone within the firm responsible for monitoring relevant R&D efforts in other countries.

Many respondents stated, however, that it would be worthwhile for FAA to monitor R&D in other countries. Table 7.1 below summarizes these results.

TABLE 3.7: R&D with Suppliers, Customers, and Non-U.S. Entities

	Affirmative Responses	
Issue	**Count**	**Percentage**
Suppliers Support Firm's Safety R&D Interests	35	81%
Influence Over Such Projects?	26	60%
Customers Support Firm's Safety R&D Interests	17	40%
Influence Over Such Projects?	13	30%
Participate in Joint R&D with Non-U.S. Entities	31	72%
Firm Monitors Relevant R&D in Other Countries	11	26%

4. Important Issues Facing Respondent's Firms

Respondents were asked to gauge the business atmosphere in which they and their firms see themselves now and in the future. In terms of the most pressing issues faced by the respondent's company, the most common responses are given below.

4.1. Current Issues

4.1.1 Business Cycle / Economy *(10 Responses)*

Given that a substantial number of the interviews (24 of 43) were conducted in the post-September 11 terrorist attack and contemporaneous economic slump, it is not surprising that the state of the U.S. economy was of great concern to numerous respondents. Many expressed concern about the length and depth of the economic decline, and stated that the cyclical nature and the resulting swings in profitability of the industry makes it difficult to invest in the business in a consistent way. These views were expressed by both airlines and manufacturing companies.

4.1.2 Air Traffic Management (ATM) Issues *(9 Responses)*

A recurring concern that was expressed by many respondents numerous times throughout the interview is great concern about the state of U.S. air traffic management (ATM) and the National Aviation System (NAS). In particular, many respondents are concerned about airspace capacity

and resulting congestion. Most believe that the system is already under great stress, and will only get worse as air traffic continues to increase. Some respondents also pointed out that the FAA and others are not taking enough advantage of the current slack in system congestion due to reduced flying in the current economic environment to make major needed improvements in the system.

4.1.3 Lack of Qualified / Interested People *(9 Responses)*

Also of great concern to numerous respondents is the perceived lack of qualified and interested people in the aviation industry. Part of this concern stems from a belief that the workforce is poorly educated and trained. Respondents acknowledged the increasing degree of technical and computer-specific skills necessary to address successfully all areas of the respondents' businesses. They noted that applicants possessing a high-school diploma and/or technical school certification increasingly do not possess the essential competencies required, especially for MRO activities. Consequently, respondents' firms were said to be responsible for more education and training than they should be.

In addition to a lack of qualified people in the workforce, there is concern that there is a lack of interest and enthusiasm for the aviation industry among today's youth. One respondent stated that it is a real challenge to keep talented people engaged in the business. Another respondent stated that "society is becoming one of $8 per hour jobs," and that it is a serious national problem that affects aviation specifically. Concern was expressed particularly about a perceived lack of engineering and aviation maintenance technician (AMT) talent, as well as a lack of people interested in these types of jobs in the aviation field. Many respondents stated that aviation is no longer considered "high-tech.," and the industry is losing qualified people to other technological fields. There was also fear that shortages would become more acute as the economy returned to normal levels and growth.

4.1.4 Lack of Clear Public Policy and Resulting Regulation *(5 Responses)*

Concern was also expressed with respect to airworthiness assurance public policy. In particular, recent public policy decisions were found to have been (1) largely reactive in nature and (2) overly driven by political concerns. In sum, respondents were concerned about the future

direction and appropriateness of civil aviation safety public policy given the current state of affairs.

4.1.5 Increasing Competition *(4 Responses)*

Many firms feared increasing competition, including a mix of aircraft manufacturers, operators, and MRO providers. Whereas respondents stated that resulting pressures would not be allowed to compromise safety, each nevertheless expressed a need to reduce costs where possible.

4.2. Concerns for the Future

The following were the most often mentioned as important issues facing respondents' firms over the next five-to-ten years.

4.2.1 ATM Systems Limitations *(5 Responses)*

Respondents are increasingly concerned with the ability of the air traffic system to cope with an increasing volume of air traffic. It should be noted that comments concerning ATM systems were neither solicited nor prompted. It is, therefore, all the more dramatic that respondents are clearly concerned about this issue.

4.2.2 Increasingly Onerous Government (FAA) Regulation *(3 Responses)*

Several respondents took exception to the paper-intensive nature of FAA oversight. Furthermore, they criticized an environment in which they feared that the FAA or private litigants could well use information voluntarily shared with the FAA against their firms in the future. In addition, some respondents indicated that they believe the government (FAA) holds back technological innovation because of onerous regulations, and as a result many good innovations never make it to market. The present situation serves to limit the flow of information that can be used to improve safety for the benefit of all.

4.2.3 Increasing Cost Pressures *(3 Responses)*

Present, unyielding pressures on costs were seen as continuing in the future. Whereas respondents affirmed commitment to sufficient funding for safety, they also expressed a need to

find cost-reducing processes and procedures to simplify maintenance and associated regulatory procedures that would support an equivalent level of safety, if not an improved one.

4.2.4 "Smart Systems" *(3 Responses)*

The view was expressed that individuals will be limited progressively in their ability to assimilate the growing technical details surrounding aircraft and their operation. As a result, there is need for "smart" computer systems to assist in overcoming this problem. Respondents expressed need for joint efforts to develop such systems and to introduce them into Maintenance, Repair and Overhaul (MRO) organizations.

5. Factors Influencing Future Firm Success

Respondents were asked to identify the factors they felt were the most influential in determining the success of their firms over the next five to ten years. The following sections discuss their non-prompted and prompted responses.

5.1. Non-prompted Responses

No individual success factor was mentioned by more than two respondents. Those factors that were mentioned twice include (1) productivity of ATC; (2) ability to cope with technology advances; (3) data and information to guide business decisions; (4) having the right products at the right price; and (5) viability of code-share partners. Of those factors cited, external forces (e.g., market and regulation) were mentioned more often that those factors determined solely from within the firm.

5.2. Prompted Responses

The following table summarizes those factors that were prompted, along with the percentage of affirmative responses.

TABLE 5.1: Prompted Responses

Issue	Affirmative Response
Competitiveness	51%
Product Prices Related to Costs	49%
Safety Performance	49%
Safety Regulation	40%
Capital Availability	37%
Data and Information Systems	37%
Labor Availability / Quality	33%
Profitability of Products	19%

6. Government R&D Investment Priorities

Respondents were asked to identify those areas in which they felt that government R&D investment should be concentrated – not necessarily limited to those areas involving safety. The following sections discuss both non-prompted and prompted responses.

6.1. Non-prompted Responses

6.1.1 Air Traffic Management (ATM) Issues *(17 Responses)*

More than one-third of all respondents mentioned, on a non-prompted basis, that the government should make investment in research addressing problems related to ATM in the U.S. a high priority. It should be noted that some responses were particularly passionate, as one respondent stated that "it's critical," while another stated that "it's a big deal, it's a national issue." This area is clearly of great concern to many in the aviation industry – and not just to aircraft operators. Airframe and component manufacturers appeared to be equally as concerned as aircraft operators about this issue because they see it as a critical factor in their own long-term success.

As noted before, respondents indicated that their primary concern was with the ATM system's ability to adapt to an increasing number of aircraft movements and to deploy necessary—often-revolutionary—technology. In particular, it was thought that airspace needs to be managed more efficiently and the reliability and accuracy of ATM systems need to be improved. One respondent suggested that the FAA emphasize accelerated development of the Local Area

Augmentation System (LAAS) while avoiding additional expenditure on the Wide Area Augmentation System (WAAS) as the latter is believed to produce limited benefits. Some respondents felt that it was the FAA's responsibility to provide this improved infrastructure since the government uniquely provides and operates the air traffic control system. Many respondents also believe the problem will get progressively worse over time, and are particularly worried about the state of ATM in 5-to-10 years time.

6.1.2 Advanced Materials *(7 Responses)*

Seven respondents indicated a concern about materials as used in aircraft and/or propulsion systems. The biggest concern expressed related to the use of composite materials in primary aircraft structures, with several respondents stating that the U.S. is lagging in knowledge in this area, particularly as it relates to the MRO and to the long-term airworthiness of these materials. In addition, some respondents indicated concern that FAA personnel involved in the certification of new materials and construction methods, as well as in the monitoring and regulation of inspection procedures related to new materials and composites, do not have the requisite knowledge. One respondent indicated that the aircraft industry has not made big enough improvements in reducing the cost and weight of materials which will be needed for new generations of passenger airplanes such as the Airbus A380 and Boeing's proposed '7E7.'

6.1.3 Human Factors *(5 Responses)*

Five respondents indicated interest in government-funded research into human factors issues. In particular, respondents stated a desire to understand better how humans interface with "machines," given the increasing technical complexity of aircraft and their sub-components, in order to make products safer. It was also expressed that more research is needed to understand the effects of fatigue on pilots and mechanics. Also cited was concern for improper practices and complacency on the part of AMTs.

6.1.4 Passenger, Baggage and Cargo *(3 Responses)*

Concern was expressed by a few respondents (all aircraft operators) that the industry needs more help in finding ways to ensure on-board security, including especially the screening of bags in an efficient manner. Included in this is the need for effective explosives detection devices, as well

as engineering assistance with modifications to make aircraft more secure (i.e., bulletproof cockpit doors).

6.2. Prompted Responses

The following table summarizes the factors that were prompted, along with the percentage of affirmative responses.

TABLE 6.1: Prompted Responses

Issue	Affirmative Response
Inspection	77%
Maintenance Training	77%
Safety Research (e.g., ATC)	70%
Safety Regulation	67%
Applied Research	67%
Public Investment Decisions	67%
Long-Range Basic Research	65%
Large Net Social Benefits	55%
Prototype Design	47%
Production Processes	33%
Private Investment Decisions	28%

Those responses that ranked near the top are discussed below.

Inspection and Inspectability / Maintenance Training

In terms of prompted responses, 'inspection and inspectability' and 'maintenance training' received the most affirmative replies, with 77% of respondents believing these factors are of concern. Respondents clearly hold that there are important opportunities to do more research to improve inspection methods, especially with new materials (such as structural composites) and electronic flight control systems (cited as 'fly-by-wire') being more complex and requiring new and improved inspection techniques to ensure their continued airworthiness. Along the same lines, the increasing complexity of new aircraft technologies was said to be the primary reason more emphasis is also needed in the area of maintenance training.

Safety Research (e.g., ATC)

'Safety research,' particularly as it relates to the ATC system, generated a very positive response, as 70% of respondents indicated that more research emphasis is needed in this area. Many

indicated that this is exactly the type of research that should be a top priority for the FAA, as it both promotes safety and is a public asset that is shared by and benefits the entire aviation community. Other comments echoed earlier discussions about the need for an improved ATM system in the U.S. as the volume of aircraft movements continues to grow.

Safety Regulation

This factor was also considered an area of significant importance to the majority of respondents, with a 67% affirmative response rate. While most respondents acknowledged that regulatory oversight is a necessary function of the FAA, many stated that there are problems with excessive or misdirected oversight and regulation. Therefore, research into regulatory processes could prove of great benefit. In addition, many argued that there is too much variability in oversight by the FAA, both by regions and by inspectors. Finally, many respondents also commented on issues related to certification, stating that certification requirements are often burdensome and do not contribute much to enhancing safety. In general, these respondents argued that there is too much focus on the "product," and not enough on new and improved "processes" and "procedures" to enhance safety. An common example given was the mandatory requirement of 16-G aircraft seats.

Applied Research

'Applied research' also garnered a 67% affirmative response rate. The theme of many comments here was that the FAA should be particularly involved in applied R&D, especially as it relates to development of improved ATM systems.

Public Investment Decisions

The majority of respondents also felt it was important for the agency to obtain data and information relevant to public R&D decisions, remarking that research should be undertaken to establish FAA's needs and procedures. Often mentioned was that such research could be used to guide the selection of those research areas considered of highest priority in a more efficient manner.

Long-Range Basic Research

The majority of respondents (65%) also believed that 'long-range basic research' should be a government-funding priority. However, numerous respondents suggested that NASA, and not the FAA, is the more appropriate agency to drive this type of research.

Those prompted responses that received the lowest affirmative response rates (i.e., highest negative responses) include 'prototype design,' 'production processes,' and 'data and information to guide private R&D investment decisions.' For the most part, respondents felt that R&D related to these factors should not be a priority for the government but should be considered primarily an industry responsibility. Even those that answered affirmatively generally included the caveat that the government should only be involved in these areas as a partner with industry.

7. R&D of Interest to the Firm

Respondents were asked to identify those issues related to airworthiness assurance that are of greatest interest or concern. The following sections discuss both non-prompted and prompted responses.

7.1. Non-prompted Responses

7.1.1 Air Traffic Management (ATM) Issues *(6 Responses)*

Again, ATM issues, particularly as related to airspace congestion, were mentioned as being a major concern to numerous respondents. The need to address ATM problems in the near-term was underscored, as these respondents envision the problem getting progressively worse as the volume of air traffic grows. Some respondents also pointed out that they believe only the FAA has the ability to put an improved system in place and make it work.

7.1.2 Training *(6 Responses)*

The need to make training more effective, particularly maintenance training and education, was underscored. Again, increasing skill requirements were noted and the increased complexity of aircraft and engines was cited. One respondent stated that airframe and powerplant (A&P)

certification, skills and abilities of many AMTs are out-of-touch with the operating realities of airlines. Thus, training is becoming more vital as the workplace and technology become more complex. Another respondent suggested that a group of individuals from FAA, industry and maintenance training schools be charged with the responsibility for and oversight of rules in maintenance and training. The standards at such schools should also be re-evaluated periodically to ensure that they provide adequate and up-to-date training methodologies, including evaluation of the use of computer-aided training and distance learning methodologies.

7.1.3 Fire, Smoke and Toxicity of Aircraft Materials *(3 Responses)*

Three respondents reflected concern about fire, smoke and the toxicity of aircraft materials and the need to perform more research to better understand and improve upon these materials. One respondent mentioned that there are not enough regulations in place related to the flammability standards for aircraft materials but that the benefits of fire- and smoke-resistant materials from a safety standpoint are clear.

7.1.4 Maintenance Errors *(3 Responses)*

Three respondents mentioned a concern about maintenance errors and their potential to degrade safety. In particular, a need for better trained people and better ways to catch human mistakes was underscored. The comments here appear to tie in very closely with those made about the need for more human factors research and improved maintenance training and education.

Other factors mentioned two times that were of concern to respondents include (1) aging aircraft, (2) fuel tank explosion prevention, and (3) aging aircraft wiring.

7.2. Prompted Responses

The following table summarizes those factors that were prompted, along with the percentage of affirmative responses and rank.

TABLE 7.1: Prompted Responses – Safety-Related R&D

Issue	Affirmative Response	Rank	Issue	Affirmative Response	Rank
Aircraft Maintenance	60%	1 (tie)	Corrosion Control	49%	10
Aircraft Repair / Overhaul	60%	1 (tie)	AMT Standards and Practices	47%	11
FAA Inspector Performance	60%	1 (tie)	Engine MRO	44%	12
Regulatory Processes	60%	1 (tie)	Engine Life Extension	40%	13
Aircraft Inspection	58%	5 (tie)	Supply of MRO Labor	37%	14
FAA Inspector Training	58%	5 (tie)	Crashworthiness	30%	15 (tie)
Polymeric Composites	58%	5 (tie)	Landing Gear	30%	15 (tie)
Aircraft Modifications	56%	8	Ceramic Matrix Composites	28%	17
Engine Condition Data	51%	9	High Temp. Aluminum Alloys	26%	18

Four factors tied for the top ranking with a 60% affirmative response rate, discussed below.

Aircraft maintenance

Respondents who believe that the quality of maintenance is not adequate cited this factor as a top concern. Numerous respondents suggested that the main current problem is lack of effective training for AMTs, coupled with the growing complexity of new aircraft. Some respondents also suggested the need for systems to be developed to replace some of the people-based aircraft inspections with "machines monitoring machines." This is particularly true for composite materials in which standards for their inspection and maintenance may not be adequate. Interestingly, 'AMT standards and practices' did not rank as high, with only 47% of respondents indicating this was a concern even though many comments related to 'aircraft maintenance' stemmed from a concern about AMT training and standards.

Aircraft Repair / Overhaul

This factor was also cited as a top concern by respondents for many of the same reasons that the quality of aircraft maintenance is considered by many to be inadequate. However, some respondents, who did not believe this was a concern, suggested that inadequate aircraft repair and overhaul is really an enforcement issue of the FAA's, not a safety R&D issue.

FAA Inspector Performance

This factor was also of great concern to many respondents. Related to this is 'FAA inspector training,' which was also a major concern, cited by 58% of respondents. Numerous comments here suggested that inspector training and performance are not adequate, with one respondent suggesting that a big part of the problem is that "the FAA is so bureaucratic and overrun with labor unions that instead of assigning the best person, you get someone who is just more senior." It should be noted that this factor elicited a passionate response by some, as they stressed that this was of *very high* concern to them.

Regulatory Processes

Finally, 'regulatory processes' was given as a top concern as many respondents believe that government (FAA) regulation imposes too many burdens on the industry that are seen as government "interference" without clear safety benefits. Such burdens include onerous paper work and data that needs to be supplied to the FAA. In addition, some respondents argue that policy is too often reactive, and driven by political interests in Congress as well as lobbyists. There is not a true regulatory mechanism in place for determining acceptable safety standards.

Other factors that generated an affirmative response rate greater than 50% are considered below.

Aircraft Inspection

Respondent comments were few, but R&D related to 'aircraft inspection' nevertheless generated an affirmative response rate of 58%.

FAA Inspector Training

Comments here tie in with 'FAA inspector performance' discussed above, namely that inspector training and performance is not adequate. Many respondents suggested that inspectors do not receive enough training and must spend too much time on paperwork.

Polymeric Composites

Generally, respondents believed that not enough is known about these materials from a construction, inspection and maintenance perspective, and they fear this lack of knowledge could have some negative safety implications.

Aircraft Modifications

Of particular concern here, especially among respondents representing general aviation (GA) firms, is the use of after-market supplemental type certificates (STCs). One respondent stated that the FAA needs to "tighten up what you can do on an STC without manufacturer involvement in the after-market." Another respondent from a GA firm stated that there are "numerous MRO shops out there making changes to our aircraft without our knowledge, and getting an STC without even undergoing flight testing." In some cases, accidents were attributed to the modifications. This issue was therefore seen by many to be a real safety concern.

Engine Condition Data

Respondent comments were few but roughly half responding believed this factor was worthy of some R&D to improve engine condition data collection and analysis.

Factors at the bottom of the ranking generated relatively little interest. These factors include 'crashworthiness,' in which most respondents stated that the focus should instead be on crash *prevention*, as well as issues related to 'landing gear,' 'ceramic matrix composites,' and 'high-temperature aluminum alloys,' all of which appear to be of lesser priority to most respondents.

8. Priorities for Data Use

Respondents were asked to indicate priorities for research related to data and information gathering, analysis or dissemination intended to enhance airworthiness assurance. The following sections discuss their non-prompted and prompted responses.

8.1. Non-prompted Responses

Fewer than half of all respondents offered a non-prompted response to this question, as it appeared that many respondents could not relate to this question. As a result, only one issue received more than two responses, discussed in Section 8.1.1 below.

8.1.1 Single Database of Incidents *(4 Responses)*

Four respondents suggested that a common, centralized database would be useful for sharing information between the FAA and industry, particularly safety information and incident reports, and/or flight data recorder (FDR) data. A centralized database of reliability and safety information could be used to identify safety issues and failure trends. Some respondents acknowledged that the creation of such a database raises issues such as how to collect the data and ensure its accuracy and integrity. (These respondents seemed unaware of FAA's history in this area.)

Other factors mentioned twice include (1) managing maintenance data, (2) too much data being gathered to permit sensible conclusions to be drawn, (3) need for better non-destructive techniques (NDT) for inspection and evaluation of aircraft materials and condition, and (4) need for more analysis of maintenance problem trends.

8.2. Prompted Responses

The following table summarizes those factors, which were prompted, along with the percentage of affirmative responses.

TABLE 8.1: Prompted Responses

Issue	Affirmative Response
Maintenance Data Storage and Management, e.g., Electronic Signatures	49%
"Inspectability" Issues	47%
Safety Performance	40%

9. Summary and Conclusions

One important method in which the FAA fulfills its mission to enhance and promote aviation safety is to undertake, or sponsor, safety-related R&D. As such, the FAA created the Airworthiness Assurance Center of Excellence (AACE) to contribute significantly toward accident rate reduction. AACE has a sizable budget to carry out, or sponsor research related to safety. The goal of this study has been to focus on the R&D agenda and to assure it is as responsive to industry needs as is practical given budgetary constraints.

In order to meet this objective, research staff at AACE member schools (primarily the Transportation Center at Northwestern University) conducted a series of 43 "revealed preference" interviews with senior executives of air carriers, major general aviation companies and their suppliers. Each interview was designed to solicit the views and preferences on issues in the area of aviation safety most relevant to the industry and the respondent's company. Both prompted and non-prompted questions were used to reveal insights into such preferences for airworthiness assurance R&D. As a result, a menu of research priorities seen as most important to this diverse group of FAA constituents emerged.

9.1. Non-Prompted Research Priorities

Table 9.1 below summarizes those safety-related areas that were mentioned most often on a non-prompted basis.

TABLE 9.1: Non-Prompted Research Priorities

Issues	Count	Rank
Air Traffic Management (ATM)	17	1
Advanced Materials	7	2
Maintenance Training	6	3
Human Factors	5	4
Fire, Smoke, Toxicity of Materials	3	5 (tie)
Maintenance Errors	3	5 (tie)

Air Traffic Management (ATM)

More than one-third of all respondents mentioned, on a non-prompted basis, that the government should make investment in research addressing problems related to ATM in the U.S. a high priority. This issue is clearly of great concern to many, and some of the responses were particularly passionate. Of primary concern was ATM systems' ability to adapt to an increasing number of aircraft movements and to deploy necessary—often-revolutionary—technology. In particular, it was expressed that airspace needs to be managed more efficiently, and the reliability and accuracy of ATM systems need to be improved. Thus, there was both a safety and an efficiency aspect to the ATM problems expressed.

Advanced Materials

Seven respondents indicated a concern about materials as used in aircraft and/or propulsion systems. The biggest concern expressed related to the use of composite materials in primary aircraft structures, with several respondents stating that they believe the U.S. is lagging in knowledge in this area, particularly as it relates to the MRO and the long-term airworthiness of these materials. In addition, some respondents indicated concern that FAA personnel involved in the certification process of new materials and construction methods, as well as in the monitoring and regulation of inspection procedures related to new materials and composites, do not have the requisite knowledge.

Maintenance Training

The need to make training more effective, particularly maintenance training and education, was underscored. Increasing skill requirements as a result of increased complexity of aircraft and engines was cited as the primary reason that maintenance training needs to be enhanced. Thus, training is becoming more critical as the workplace and technology become more complex.

Human Factors

Respondents also indicated strong interest in government-funded research into human factors issues. In particular, respondents reflected a desire to understand better how humans interface with machines, given the increasing technical complexity of aircraft and their sub-components in order to make products safer.

Fire, Smoke, and Toxicity of Aircraft Materials

Several respondents indicated concern about fire, smoke and toxicity of aircraft materials, and the need to perform more research to better understand and improve upon these materials, as well as ensure the appropriate regulations are in place.

Maintenance Errors

Several respondents also mentioned a concern about maintenance errors and their potential to degrade safety. In particular, a need for better trained people and better ways to catch human mistakes was underscored. The comments here appear to tie in very closely with those made about the need for more human factors research and improved maintenance training and education.

9.2. Prompted Research Priorities

Table 9.2 below summarizes the affirmative response rate for those safety-related areas that were prompted to all respondents.

TABLE 9.2: Prompted Research Priorities

Issue	Affirmative Response	Rank	Issue	Affirmative Response	Rank
Aircraft Maintenance	60%	1 (tie)	Corrosion Control	49%	10
Aircraft Repair / Overhaul	60%	1 (tie)	AMT Standards and Practices	47%	11
FAA Inspector Performance	60%	1 (tie)	Engine MRO	44%	12
Regulatory Processes	60%	1 (tie)	Engine Life Extension	40%	13
Aircraft Inspection	58%	5 (tie)	Supply of MRO Labor	37%	14
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Aircraft Modifications	56%	8	Ceramic Matrix Composites	28%	17
Engine Condition Data	51%	9	High Temp. Aluminum Alloys	26%	18

The top four research priorities are briefly summarized below.

Aircraft Maintenance

Respondents who believe that the quality of maintenance is not adequate cited this factor as a top concern. Numerous respondents suggested that the main problem is a current lack of effective training for AMTs, coupled with the growing complexity of new aircraft. Some respondents also

suggested the need for systems to be developed to replace some of the people-based aircraft inspection, or "machines monitoring machines."

Aircraft Repair / Overhaul

This factor was also cited as a top concern by respondents for many of the same reasons that the quality of aircraft maintenance is considered by many to be inadequate. However, some respondents, who did not believe this was of concern, suggested that inadequate aircraft repair and overhaul is really an enforcement issue faced by the FAA, not a safety R&D issue.

FAA Inspector Performance

Numerous comments here suggested that inspector training and performance are not adequate, as it is believed that inspectors do not receive enough training and must spend too much time on paper work.

Regulatory Processes

Finally, 'regulatory processes' was cited as a top concern as many respondents believe that government (FAA) regulation imposes many burdens on the industry that are seen as government "interference" without clear safety benefits. Such burdens include onerous paper work and data that needs to be supplied to the FAA. In addition, some respondents argued that there is not a true regulatory mechanism in place for determining acceptable safety standards.

9.3. Potential Further Research

It is suggested that consideration be given to FAA sponsoring a limited series of "revealed preference" interviews with appropriate FAA Headquarters and Regional Headquarters executives to determine their preferences--individual preferences--with respect to FAA's R&D agenda with emphasis on safety ("airworthiness assurance"). In addition, similar interviews are recommended with a limited number of senior NASA Headquarters and NASA Center executives for the same purpose. It is important to determine how well the perceptions and preferences of industry and relevant government executives match. It will not only serve to enhance the value of FAA safety R&D projects, but it may well help to establish new, more stable common ground between FAA and NASA where such efforts are concerned.

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