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Safety research at the U.S. FAA center of excellence for commercial space transportation

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ABSTRACT

Commercial space research is different in many ways when compared to space research historically conducted by military and governmental space organizations. Differences in possible topics, subjects, and technology characteristics drive researchers to search for different types of solutions to what seem to be familiar problems. A research consortium sponsored by the United States (US) Federal Aviation Administration (FAA), the Center of Excellence for Commercial Space Transportation (COE CST), was established in 2010 to facilitate collaborative research activities with a specific emphasis on the commercial aspects of space-related research. Major research areas have been identified that encompass as many possible research topics as could be imagined (as they are pertinent to commercial space activities). The first research domain focuses on the operational challenges of integrating commercial space activities into the national air space (NAS), the management of space "traffic" on-orbit, and the safe operations of spaceports. The second research area most resembles the governmental space research activities, with an emphasis on engineering of systems, subsystems, operations, and analyses surrounding the vehicle and its safety. The third research area encircles the human as a part of the space activity. Research on physiology, human factors, human rating, and training are some of the primary concerns of this domain. Finally, research based in the social sciences are included to study the markets, policy, law, and regulatory environments that will be required to ensure long-term viability of the evolving commercial space industries.

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1. Introduction

This paper discusses the domain of commercial space transportation research as it has been conceived by a group of academicians, government officials, and members of private industry. The differences between space research and commercial space research may not be easy to recognize, but can be exemplified with a few anecdotes. The first, attributable to Dr. Richard Jennings of the University of Texas Medical Branch (now retired) is related to research on human subjects to study the effects of suborbital flight acceleration profiles (commonly referred to as "g-profiles") on a class of people who would represent the pool of potential customers. In a very similar fashion to the historic testing that was performed by various military and research organizations, the human subjects were placed in a cabin at the end of a large centrifuge arm. As the arm begins spinning, the orientation of the cabin is controlled to give the subject the sensation of single or multi-axis g-forces, simulating the desired flight profile under study.

One difference between space research and commercial space research is that no military or government research organizations have ever had a mission goal that would require the study of suborbital flight profiles on human subjects, unlike some commercial, non-governmental space companies. This comparison highlights the differences in the types of missions between the governmental and non-governmental space activities.

Additionally, the subjects that were selected for study under the governmental programs were very different. Dr. Jennings would show a photograph of a baby bottle, soft-drink bottle, beer bottle, and an intravenous (IV) fluid bag, side by side, depicting the

Abbreviations: AACE, Airworthy Assurance COE; ACER, Airliner Cabin Environment Research Center; ASCENT, Alternative Jet Fuels and Environment; ASSURE, Alliance for System Safety of UAS through Research Excellence; AST, Office of Commercial Space Transportation (organization code); CEAT, Center of Excellence for Airport Technology; CGAR, COE for General Aviation Research; COE, Center of Excellence; COE CST, Center of Excellence for Commercial Space Transportation; COMSTAC, Commercial Space Transportation Advisory Committee; ECLSS, Environmental Control and Life Support System; FAA, Federal Aviation Administration; FY, Fiscal Year; GEO, Geosynchronous Earth Orbit; GTO, Geosynchronous Transfer Orbit; IV, Intravenous; JAMS, Joint Center for Advanced Materials; LEO, Low Earth Orbit; MEO, Middle Earth Orbit; NAS, National Airspace System; NEXTOR, National COE for Aviation Operations Research; PARTNER, Partnership for Aircraft Noise & Aviation Emissions Mitigation Research; PEGASAS, Partnership to Enhance General Aviation Safety, Accessibility and Sustainability; REDAC, Research, Engineering & Development Advisory Committee; SUSTAIN, Center for Human Training and Technical Performance; US, United States; UAS, Unmanned Aircraft Systems.

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phases of aging (from very young, to very old). The governmental research programs all studied subjects who would be best categorized by the beer bottle. The commercial space research in these g-force studies, on the other hand, included subjects from stages of life characterized by the soft-drink bottle to the IV bag. This vignette demonstrates that the scope of research possibilities is constrained in different ways between the two types of research.

Furthermore, not only was the range of subject ages vastly different, but the physical condition of subjects was specifically selected to be different. Subjects in recent experiments were selected to exclude healthy individuals.[1] People with neck and back injuries, asthma, diabetes, and other common disease states were sought, because these individuals best represented the potential customer pool for commercial space companies. This highlights a difference of research focus areas, between one set of research opportunities appropriate for governmental research, and an entirely different set of opportunities (with the express exclusion of the governmental set) for commercial space research.

Finally, turning to a different research activity to explain another important difference, it can be seen that governmental research tends to focus on a technology's capacity (also referred to as performance or functionality) and reliability. This is neither unexpected nor inappropriate in any way. Since the government tends to focus on research areas where the private sector underinvests (because they are too high risk, or have no apparent commercial application), these technologies are commonly seen as "cutting edge," and the emphasis is on attaining a desired level of performance and safety (aka "reliability"). As described by Christensen [4], these are the first two bases of competition and demand for any new technology. As such, it is appropriate that governmental space requirements are focused on these characteristics. Commercial space research, however, tends to focus on the bases of demand that follow functionality and reliability, namely customer convenience and cost. For example, a current commercial space research task is the development of a ceramic-nanotube material that can be easily manufactured, applied, and is inexpensive to make and buy. The last significant difference between governmental and commercial space research is the focus on these latter bases of competition and demand, instead of on the former.[2]

The rest of this paper describes the COE CST, started by the FAA Office of Commercial Space Transportation (AST) in 2010. It continues to describe the four research areas that comprise a large domain of possible research topics in operations, engineering, human research, and the social sciences. Examples of research being conducted in these areas by the COE CST are given, and the paper concludes with a brief discussion of the linkages and interdependencies between these four research areas.

2. The FAA COE CST

2.1. Context

This section provides general background information about the overall FAA Centers of Excellence program, the FAA AST, and the COE CST. The section concludes with a brief status update of the COE CST.

2.1.1. FAA centers of excellence program

The Center of Excellence program was created with the passage of an authorization bill for the FAA in 1990 [18]. Each COE is a collection of universities, selected through a competitive process, with guaranteed federal funding for a ten year term. Each research consortia is designed to aggregate the needs of government, industry, and academia around a specific industry context or domain, with the purpose of conducting research, training, and outreach. All federal funding of COE research tasks are required to be matched, in cash or in kind, through contributions of the universities or industry members. As summarized in Table 1, COEs provide benefits that are not achievable by independent research grants, including workforce development, innovation creation and diffusion, and alignment with industry needs [12]. A major operational goal of all COEs after the ten-year milestone is to operate without solely relying upon FAA funding.

To date, 13 COEs have been created. Of these, eight are no longer in existence, most commonly due to the ten-year term as prescribed by law. Two were "reincarnations" of COEs that were established through a competitive process subsequent to the exit of a previously existing COE. Five are within the ten year term of their establishment. The complete set of COEs and their status is shown in Table 2.

2.1.2. FAA office of commercial space transportation

The Department of Transportation's Office of Commercial Space Transportation was created with passage of the Commercial Space Launch Act [10]. This office was transferred to the FAA in 1995 [15,21] and become known as "AST" which stood for the Associate Administrator of Commercial Space Transportation. Because the office was transferred as a direct Line of Business within the FAA, it and was given authority to report directly to the FAA Administrator. . The office has the responsibility to regulate the launch, reentry, and site operations for all non-governmental space activity in the U.S., with the multiple goals of protecting the safety of the uninvolved public and government property (commonly referred to as the "safety" goal), and promoting the safe and successful commercial space activities (also known as the "promotion" goal), and protecting the national security and foreign policy interests of the US government that is generally an implicit goal.

The phrase "commercial space industry" is a quite broad set of industry segments that can be narrowed by focusing on the "commercial space transportation industry."[3] include companies of various sizes (as measured in any number of typical metrics, including number of employees, annual revenues, annual profits, etc.), ages, strategic groupings (e.g., generalist or specialist) [16], operating regimes (e.g., "suborbital," "orbital", space tourism, manned, unmanned), demand groupings (e.g., "high mass to orbit," "low mass to orbit"), and vehicle types (e.g., "balloons," "winged vehicles"), for example. A partial list of current and potential commercial space transportation industry segments are given in Table 3.

Research that focuses on the needs of these demonstrated and potential commercial space transportation industry segments is an important factor for their long-term viability. The research conducted by FAA AST help fulfill the safety and promotion goals of the organization. Research is an important exploratory component of organizational learning [19] that AST employs to perform its safety mission more effectively. With respect to the promotion goal, research is a critical contribution that falls primarily on the government for the purpose of stimulating industry growth,[4]

[1] You read that correctly!

[2] A complete description of the four bases of demand, and the structure and characteristics of markets and industry as technology evolves through them, is described in disruption innovation theory [5,6].

[3] This industry segment qualification better aligns the discussion to the mission of the AST, and is applied here to limit the number of industry segments discussed. The same analysis, however, could also be applied to the non-transportation commercial space segments.

[4] A common argument that encourages government investment in research activities identify the private sector's persistent underinvestment in R&D due to significant spillover effects [2], social returns that are greater than the private returns [20], market failures of "low appropriability and capital market imperfections" [3], and "deadweight losses due to monopolistic pricing" resulting from joint ventures, mergers and acquisitions, and other cooperative arrangements between competing

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