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THE DEVELOPMENT OF A COMMERCIAL SPACE TRANSPORTATION LESSONS LEARNED DIGITAL DOUMENT COLLECTION ACCESSIBLE ON THE NMSU WEBSITE

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Abstract: In a paper delivered to the IAC in 2014, the FAA Center of Excellence for Commercial Space Transportation discussed the work being conducted on the Development of a Framework to Capture a Body of Knowledge for Commercial Spaceport Practices. While that work continues today, it does not contain information on the lessons learned from the accidents and incidents that have occurred recently in the commercial spaceflight industry. There is a need to quickly and easily obtain the information that has is available in public documents developed as a result of commercial spaceflight incidents and accidents.

The Spaceport Framework is accessible on the web through the New Mexico State University (NMSU) Library Digital Collections (http://content.dm.nmsu:2011/cdm/). This website actually contains a Document Collection System that allows the user to directly go to documents that are either in the Library or within another website. The FAA has developed a Lessons Learned list of aviation Accident Threat Categories and Aviation Accident Groupings, many of which relate to commercial space transportation. Therefore, the Document Collection System will allow the causes of recent commercial space incidents and accidents to be easily accessible to anyone using the NMSU Digital Collection.

Results: The FAA Accident Threat Categories include Fuel Tank Ignition, Landing Takeoff Excursion, Structural Failure, Flight Deck Layout/Avionics Confusion and other areas that have been the cause of accidents and incidents. The number of public documents which identify the causes of accidents and incidents in the Commercial Space Transportation industry is unfortunately increasing as the number events increase. This is a new industry and will be able to learn much from reviewing the recent past and the capability to use a document management system (DMS) will make this task easier to accomplish.

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INTRODUCTION OF THE RESEARCH PROBLEM

Objective of the Research

The objectives of the research are to update the descriptions of the current spaceport environment; discuss new spaceports in the United States and the United Kingdom; and expand the Spaceport Body of Knowledge (BOK) and the document management system that allows the user to go directly to the underlying documents to include the Lessons Learned from accidents and incidents that have occurred recently in the commercial spaceflight industry. Specifically determine the applicability of the FAA Accident Threat Categories and the Aviation Accident Groupings that were developed for the aviation industry.

Each spaceport developer and operator must currently research and develop safety and operational guidelines for their specific location. This project has been established to update the Spaceport Framework Body of Knowledge. New descriptions have been added to make each of the ten categories clearer. New categories (eleven and twelve) have been added to include commercial space transportation accident and threat categories based upon the Federal Aviation Administration categories and definitions of terms used.

Once again, as commercial space transportation procedures and standardized documents are not available for each category and subcategory, reference documents include those from Federal Ranges (NASA and the Air Force), FAA standards, and examples from European Space Agency documents.

Methodology

The Spaceport BOK and Framework is accessible on the web through the New Mexico State University (NMSU) Library Digital Collections , http://contendm.nmsu.edu. This website contains the Document Management System (DMS) that allows the user to go to documents that are either in the library or on another website. This paper will discuss the current spaceport environment and the development of definitions for each Framework category; in addition we will evaluate the expanded Framework to include Lessons Learned based upon the FAA list of Aviation Threat Categories and Aviation Accident Groupings. This expansion is expected to make the results of accident and incident investigations easier to access.

Description of the current Spaceport Environment.

"Every Spaceport is different, and each is typically designed to support specific types of vehicles…Some spaceports, like MojaveAir and Space Port (KMHV) are collocated with a public airport . Others, like Spaceport America (9NM9) in New Mexico, are built for a specific purpose.

There are currently 10 active spaceports with FAA launch site operator licenses, which are located in Florida, Texas, California, New Mexico, Alaska, Virginia, and Oklahoma. An operator license authorizes launches or reentries from one site within a range of operational parameters of the same family of vehicles that are transporting specified classes of payloads or performing specified activities.

An operator license remains in effect for five years from the date it's issued." [1]

Over the past three years, the FAA has licensed Launch Sites (Spaceports) in Texas to Midland International Airport and Ellington Airport, the latter is part of the Houston Airport System. This expansion of the Spaceports was supported by existing airports and their communities to develop an infrastructure to support the future development of space based activities. The development of the spaceport is part of a planned set of activities to draw more companies to the area that are working in the space transportation industry.

In Europe, several spaceport locations have been studied including one in the United Kingdom. " The British commercial spaceport competition was a plan by the UK government announced in early 2014 to select a site, build a commercial spaceport, and have it in operation by 2018. Althought six sites were shortlisted for possible selection by 2015, the competition was ended without a selection in May 2016, and replaced with a statement from the UK government regulatory agency tha they would support rules that would allow a commercial spaceport to be built at any suitable location."[2] "To avoid restricting the development of the UK market, the government will create the regulatory conditions for any suitable loactin that wishes to become a spaceport, to take the opportunity to edevelop and attract commercial space business…"[3]

Over the past few years there have also been several locations in the US that have been attempting to develop Spaceports. These include locations in Texas Georgia, and Hawaii.

Blue Origin Spaceport (West Texas launch site)- Blue Origin completed the environmental assessment for it's West Texas launch site in 2014. They propose to launch and land various suborbital RLVs as part of its launch vehicle development program. In order to accommodate the launch activities, the FAA issues experimental permits and/or launch licenses to Blue Origin that allow Blue Origin to conduct launches of these vehicles from the West Texas launch site. Blue Origin determined that to support the proposed RLV activities, additional construction would be required. All construction activities would occur within the Blue Origin property line. In addition to permitted/licensed launches and construction, Blue Origin may conduct ground testing activities and amateur launches at the launch site. From 2014 thru June, 2016 Blue Origin has conducted the following launches:[4]

[1] Paul Cianciolo, FAA Safety Briefing pp28-31, May/June 2016.
[2] Wikipedia, British commercial spaceport competition, June 19, 2016.
[3] Helen McArdle, News Reporter for the HeraldScotland, May 20, 2016.

[4] FAA Web Site – List of Permitted Launches, 7/5/2016 http://www.faa.gov/data_research/commercial_space_data/launches/?type=Permitted

Jul 19, 2016	Research and Educational Payloads	New Shepard System	Blue Origin	Texas
Apr 2, 2016	Crew Capsule PM4 M4	New Shepard System	Blue Origin	Texas
Jan 22, 2016	Crew Capsule PM4 M3	New Shepard System	Blue Origin	Texas
Nov 23, 2015	Crew Capsule	New Shepard System	Blue Origin	Texas
Apr 29, 2015	No payload	New Shepard System	Blue Origin	Texas

Spaceport Camden (Georgia) -The FAA released a report of the scoping meeting it held in December, 2015. It states that the "The Federal Aviation Administration (FAA) is preparing the Spaceport Camden Environmental Impact Statement (EIS) to evaluate the potential impacts of the Camden County, Georgia, Board of Commissioners' (the County's) proposal to develop a commercial space launch site ("Spaceport Camden"). Under the Proposed Action presented during the public scoping comment period, the County would construct and operate Spaceport Camden, which would consist of a vertical launch site, a landing zone, a control center complex, and another facility similar to the control center that would include provisions for visitors and viewing launches."[5]

This Scoping Summary Report provides an overview of the activities conducted and the comments received during the public scoping comment period for the Spaceport Camden EIS, which began with issuance of the Notice of Intent (NOI) to prepare an EIS, Open a Public Scoping Period, and To Hold a Public Scoping Meeting in Camden County, Georgia (80 Federal Register 68893) on November 6, 2015."[6]

Spaceport Hawaii – Has been actively developing an Environmental Impact Statement that will meet FAA's requirements. " For several years, a small office in the state's Department of Business, Economic Development and Tourism has been pursuing a spaceport certification for Kona International Airport, which would make it one of the few hubs for proposed commercial flights into suborbit. Jim Crisafulli, State Office of Aerospace Development director, said an environmental assessment required for the Federal Aviation Administration certification remains in the works.

He estimates a public meeting regarding its findings could be held this summer, perhaps by late July or early August. "[7]

The Framework for Spaceport Operations developed a taxonomy that defined groups on the basis of shared characteristics and gave names to these groups. Recently definitions have been added to the categories and two additional catagories were added that included category 11, Accident Threat categories and category 12, Accident Groupings.

The major categories were labelled:

1. Airfield and Launch Operations
2. Site Security
3. Emergency Response
4. Visitor Management

[5] FAA Scoping Summary Report, Spaceport Camden Environmental Impact Statement, April 2016.

[6] Ibid

[7] TOM CALLIS Hawaii Tribune-Herald, May 23, 2016

5. Ground and Flight Safety

6. Environmental Management

7. Mission Readiness

8. ITAR Requirements

9. International Coordination among Spaceports

10. Self inspection

11. Accident Threats

12. Accident Groupings

A summary of Categories 1 through 10 were provided in a paper published by the IAC in 2014. The two new categories (11 and 12) and their subcategories are defined as follows and are included as **Attachment A** of this paper:

11. Accident Threat Categories - Accident summaries organized relatie to the theat category that was a major factor in each accident.

11.1 Collisions -This category includes accidents or mishaps caused as a result of a collision. Collisions may take place between launch vehicle or spacecraft and objects on the spaceport, in the air, or in space.

11.11 Collisions between a vehicle with an object on the spaceport - Collisions between a launch or rentry vehicle or a spacecraft with objects on the spaceport. This section discusses accidents and incidents where a collision occurred between an launch or reentry vehicle and an object on the spaceport (e.g. personal car, emergency vehicle, bus, building, etc.)

11.12 Collisions between a vehicle with an object in the air - This section discusses accidents and incidents where a collision occurred between an launch or reentry vehicle and an object in the air (bird, aircraft, debris, etc.)

11.13 Collisions between a vehicle with an object in space - This section discusses accidents and incidents where a collision occurred between a launch or reentry vehicle and an object in the space (e.g. debris, another space vehicle, etc.)

11.2 Fuel exhaustion -This section discusses accident threats that arise from a depletion of fuel. This fuel may be used during any part of the launch or reentry and may be exhausted due to mechanical or hydraulic failure or continued use of the fuel until it ran out.

11.3 Fuel tank ignition - Fuel tank safety has been predicated upon the absence of any form of heat or spark within the fuel tank. However, accidents in this category were caused by a some form of an anomolous ignition problem.

11.4 Inclement weather - While current launches are usually conducted in good weather, when scheduled commercial operations commence there may be launches conducted under less than optimal conditions. Accidents and incidents that occur due to launch and reentry activities in poor weather will require the development of more robust designs and operational techniques and a better understanding of environmental threats.

11.5 Incorrect piloting technique - Mistakes which result in an accident or incident made by a pilot with low-time in the cockpit may be the result of training, design errors, ommunications or a combination of these and other factors. The accidents referred to in this section are often the result of a series of events culminating in an accident or incident.

11.6 In-flight upsets - Accidents resulting from in-flight upsets range from external atmospheric anomolies to internal failures such as flight control or structural failure.

11.7 Multiple system failures - lack of system isolation - Lack of system isolation involves a condition where a malfunction or failure condition affects more than one system, or cascades into a series of failures. This may result from a structural failure, a fire, or the system architecture.

11.8 Launch or landing excursions - Launch and landing excursions have been a factor in accidents and incidents. In aviation this has resulted in changes to runway operations and the addition of rapid deceleration areas.

11.9 Air and ground incursions - The purpose of Air and Ground Traffic Control is to separate aircraft and spacecraft so they do not collide. Accidents incuded in this category occur when appropriate assignments are not given or followed.

11.10 Pressurization and decompression failures - Space vehicles fly at altitudes that require pressurization to sustain human life. Loss of pressurization presents different hazards depending on how quickly the loss occurs. Without pressurization occupants can suffer from extremely cold temperatures as well as lack of oxygen.

11.11 Uncontained engine failure - With new engines being developed there is little knowledge about the failure modes for each engine. These failures may result in external explosions and debris penetrations into the fuel tank, the electrical or mechanical systems and the structural system. However, as a result of ealier failures lessons were learned about methods that could reduce the potential for failures as well as steps that could be taken to protect the crew and passengers.

12.0 Accident Groupings - Advancements in technology, training, and processes will result in improvements in nearly all areas of commercial space transportation safety. However, four groupings continue to represent significant opportunities for additional safety improvements. They are included here as they may also assist in understanding the lessons learned from space flight within these four groups.

12.1 Loss of control - Loss of control is a significant, unintended departure from a normal/expected trajectory, characterized by a transition from a stable condition into an unstable condition that precludes rapid recovery.

12.2 Controlled flight into an object - This occurs when a space vehicle is flown under pilot control into an object (another space vehicle, station, the water, or into the ground) with inadequate awareness on the part of the pilot of the impending collision.

12.3 Launch or reentry - An accident that occurs during a launch or reentry or during a normal evasive procedure (e.g. restarting an engine before landing).

12.4 Automation - Automation has provided significant improvement in nearly every aspect of launch and reentry operation. However, gaps still exist in automation systems and in the automation/human interface.

As part of our research we have reviewed several space launch accidents and have found that the causes of these accidents is contained within the categories mentioned above.

For example, Section 11.3, Fuel Tank Ignition, has been the cause of the failure of the Challenger in 1986 and to the SpaceX CRS-7 launch failure on 6/28/2016. In the first case it was due to launching the Space Shuttle while temperatures were too low, causing a failure in the "O" rings and in the second case it was due to a strut failure, despite tests that indicated that the struts could stand the anticipated stress. These two mechanical failures can easily be compared when using this document management technique.

Section 11.5, Incorrect piloting technique includes the in-flight breakup of SpaceShip Two on October 31, 2014. A summary of the accident is provided in the database along with a link to the National Transportation Safety Board Report. The report states that the copilot unlocked the feather earlier than expected which resulted in the feather extension and resulting in the catastrophic structural failure. The NTSB report includes recommendations that are consistent with improvements in pilot training and techniques as well as improved communications between the launch operator and the FAA.

Section 11.11, Uncontained engine failure captured the cause of Orbital's Orb-3 accident investigation report. It was agreed by both Orbital and NASA that the cause of the accident (explosion of the AJ26 Rocket engine)was an explosion of the liquid oxygen turbopump which from rotor radial positioning which provided the initial ignition and fire.

Additional launch failures are now being added to the document management system

The Documentation Management System:

Libraries of all types have been increasingly focused in recent years on the creation of digital collections that go beyond traditional physical collections to give users worldwide access to unique cultural heritage and research materials, and the NMSU Library was no exception. In 2009 the Library began the process of beginning dedicated digital collection activities by hiring its first Metadata Librarian, and in 2010 the Library acquired CONTENTdm, digital asset management (DAM) software that allows libraries to organize, describe, and present digital collections to users.

By partnering with the Library for document management and description, NMSU would be able to house the BOK in a system that offered document storage, linking to documents and websites, full-text keyword search capabilities, and rich description of each item, including the use of authorized subject heading from the NASA Thesaurus. The items could be organized according to their placement in the Framework, and users would have the option to filter their results at various levels of the Framework.

Configuration of the Body of Knowledge

The first step the Library took was to meet with the project stakeholders to determine the needs and goals of the collection. This includes determining specifications for digitizing physical objects (when necessary), any special copyright or access issues surrounding the items in the collection, the metadata elements needed to best describe the collections for both the users' and administrative purposes, and workflows for the various tasks involved in creating the collection. To this end, the Library's Associate Dean and Metadata Librarian began attending the Team's teleconferences in early 2012.

Item storage and access

One of the first determinations to be made was on the presence of actual documents within the collection. Because the value of the project was not in the creation of new material but the consolidation of material under the umbrella of the Framework, it was a given that the material selected would already exist on the Internet in some form. It was entirely feasible that the BoK could be a mere collection of links, classified according to the Framework categories.

The Library created five fields to contain information related to the Framework levels. The *Framework Category* field is visible to the user and indicates the lowest Framework level into which the item is parsed. The *Top Category, First Subcategory, Second Subcategory, and Third Subcategory* fields are not visible to the user and indicate all the levels of the Framework into which the item is parsed. Therefore, the metadata for an item whose final parsing is into category 5.5.1 would also include indications that the item fits into the Top Category 5.0 and the First Subcategory 5.5.

The work that began in the Library during the Spring 2012 semester was that of configuration and preparation in advance of full-swing submission of items to the BOK. Since that time information has been added to the database annually, and in this year, the Accident Threat Categories and the Accident Groupings have been inserted.

Use of the online digital collection on the Framework for Spaceport Operations is consistent. We are reporting 5,040 searches from August 2015-2016.

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The author is the founder and Curator of this annual conference which is focused on providing a snapshot of the commercial space industry at the time of the conference each October. Virgin Galactic's global operations center is located at Spaceport America, 30 miles from the site of the conference in Las Cruces, New Mexico. Other launch operators with commercial spaceports who attend regularly include Blue Origin, SpaceX, and Orbital ATK. Commercial spaceport representatives who attend include Midland Air & Space Port and Spaceport Colorado. This gathering of the commercial space industry's leaders delivers a cohesive message about the importance of collaboration and partnership across the globe. Government enablers include NASA's Commercial Crew and Cargo programs, the FAA's Office of Commercial Space Transportation. United Launch Alliance is a consistently innovative supporter of the industry along with the European Space Agency's Arianespace, a primary supporter of this conference since inception.