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A Study of 2008-2009 Mean Scheduled Launch Days as a Key Factor for Planning Future Commercial Scheduling and Resource Allocations at Cape Canaveral Spaceport

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Title: A STUDY OF 2008-2009 MEAN SCHEDULED LAUNCH DAYS AS A KEY FACTOR FOR PLANNING FUTURE COMMERCIAL SCHEDULING AND RESOURCE ALLOCATIONS AT CAPE CANAVERAL SPACEPORT

INTRODUCTION

Background of the Problem

As commercial space transportation demand increases, so will the number of scheduled launch dates. The aerospace industry is very different from other industries in the United States of America (USA). According to Wensveen "The combination of technological uncertainty and long lead times, often 7-10 years and frequently longer, between program initiation and completion, makes advance estimation of cost particularly difficult" (Wensveen, 2008, p.6). Space Exploration Technologies Corporation (SpaceX) is in the process of shifting the 20th Century USA vertical launch vehicle, space transportation manufacturing/assembly/testing/launch paradigm into the lean and cost efficient 21st Century USA vertical launch vehicle, space manufacturing/assembly/testing/launch paradigm defined on their website as follows:

> In an era when most technology based products follow a path of ever-increasing capability and reliability while simultaneously reducing costs, launch vehicles today are little changed from those of 40 years ago. SpaceX aims to change this paradigm by

> developing a family of launch vehicles which will ultimately reduce the cost and increase the reliability of space access by a factor of ten. Coupled with the newly emerging market for private and commercial space transport, this new model will re-ignite humanity's efforts to explore and develop Space.
>
> (SpaceX, Company Overview, n.d.)

Future vertical launch spaceport operations teams and customers will need to know the parameters associated with vertical launch scheduling to properly plan launching from the Cape Canaveral Spaceport. This includes the mean number of days between initial and actual launch dates, the mean number of reschedule dates, and the mean number of days between initial and reschedule dates per mission. There does not appear to be any collective data analysis of this sort concerning vertical launch schedules from Cape Canaveral Spaceport. Providing analysis, for the 2008-2009 vertical launches, at this site, will provide a preliminary glimpse of key factors to spaceport launch operation teams and customers to properly allocate resources and forecast vertical launch support system supply and demand requirements.

History

The decision to designate Cape Canaveral as the USA's vertical launch vehicle spaceport, for payload and human spaceflight, was made for very specific reasons. This location offers an eastern launch inclination, a safe distance from populated areas**,** over the vast expanse of the Atlantic, placing the hardware far above population's harm, and into orbit. Seller's states " …the benefit of being closer to the equator for equatorial orbits, and the added velocity from the Earth's rotation rate…" (2005, p.614) were the other key factors. Cape Canaveral was designated as the Air Force's Eastern Test Range in 1964. The Mercury and Gemini missions launch from this site under the control of the

Air Force's 45th Space Wing (45th SW). When the National Aeronautics and Space Administration (NASA) embarked on the Apollo program, they moved the John F. Kennedy

Space Center (KSC), human spaceflight launch operations, to Merritt Island where they constructed launch complexes 39A and 39B. The State of Florida/KSC/45th SW, under the State's space agency, created a Spaceport Master Plan for the State, in 2002, and designated the areas of Cape Canaveral Air Force Station (CCAFS) and KSC as the Cape Canaveral Spaceport. The State of Florida's recently completed Spaceport Master Plan 2010 refers to this site as the Cape Canaveral Spaceport, as well. This definition serves as the collective description of spaceport activities within the CCAFS/KSC areas, as the State's space transportation, multimodal system component. The other components are air, sea, rail, and highway systems. The Cape Canaveral Spaceport is fortunate to have all four systems strategically tied into their daily activities to support vertical launch activities taking people, goods, and services outside our atmosphere and beyond. The environment outside our atmosphere has been our frontier for the last 51 years.

The space launch enterprise has been historically championed by the Department of Defense (DOD) and the NASA in the USA. The International Space Station's (ISS) requirements concerning re-supplying and ferrying humans to and from the world's first space outpost moved the NASA decision-makers to engage with national commercial space transportation organizations to perform these functions after the Shuttle program retired. This program is the Commercial Orbital Transportation Services (COTS) program. CCAFS, under the umbrella of the 45th SW, is currently engaging with Space Command's 'Launch Enterprise Transformation' to support future DOD, civil, exploration, and commercial launch efforts from licensed launch pads on their site.

"Lockheed Martin Commercial Launch Services – Space Launch Complex (SLC) 41, United Launch Alliance (ULA)- SLC 37, and SpaceX-SLC 40 operate and launch from CCAFS, and hold Active Launch Licenses from the Federal Aviation Administration (FAA)/Aerospace Transportation (AST). The State of Florida's aerospace agency, Space Florida (SF), has an Active Site Operator License for SLC 46" (U.S. DOT, FAA(n.d.) Active

Licenses) designed to support solid launch vehicle activities, at CCAFS. Though CCAFS is a DOD site, the need to support commercial space transportation requirements, with regard to national security, communication, remote sensing, exploration, experimentation, and human space flight, has been recognized. The utilization of this area for its original purposes is being understood anew. KSC is restructuring SLC 39B as the Space Launch System launch platform. SpaceX is retrofitting SLC 39A to support the Falcon9 Heavy Launch platform.

The infancy of nonfederal, contracted, commercial space transportation is at hand. Future commercial launch transportation interest and demand is increasing. New information system architecture will need to be created to support the future multi- customer/multi-mission launch operations. Launch site, facilities processing, and launch operators, along with launch and payload customers, will need to know the parameters associated with launch scheduling at Cape Canaveral Spaceport, to properly allocate resources and forecast launch support system demand requirements.

Statement of the Problem

The purpose of this study is to analyze the Cape Canaveral Spaceport actual launch schedule dates, delineated as initial, rescheduled, and actual launch dates, tracking only those mission launches with actual launch dates between January 1, 2008 and December 31, 2009, to identify scheduling parameters for commercial space transportation allocation of spaceport resources based on the variables identified in the sub problems.

Sub problems

The first sub problem is to estimate the mean number of days between the initial scheduled launch date and the actual launch date.

The second sub problem is to estimate the mean number of times a launch was rescheduled per mission.

The third sub problem is to estimate the mean number of days between the scheduled dates per mission.

The fourth sub problem is to investigate the percentage of planned scheduled launches vs. actual launches at Cape Canaveral Spaceport.

Assumptions

1. The data taken from the Space Flight Now Launch Log is correct
2. This researcher captured the Space Flight Now Launch Log data correctly
3. The dates used for the analysis are Greenwich Mean Time (GMT) dates

Delimitations

1. The lack of time to gather significant insight or data from the 45th SW, 1Range Operations (ROPS) Scheduling and the NASA scheduling authorities
2. The time factor required to support new preliminary research
3. This researcher's capacity as a novice in this field
4. Lack of consistent time reporting throughout Spaceflight Now Log, some entries did not specify a specific day, but rather an early or late month entry.
5. The findings and conclusions will be based on an investigation of the variables identified in the problem statement and sub problems.
6. Unidentified confounding variables may have a negative impact on the findings and conclusions.
7. Although the research report is free of intentional bias, the researcher recognizes the probability of bias of some type and cautions the reader to be cognizant of that likelihood.

Definition of Terms

Cape Canaveral Spaceport – Cape Canaveral Air Force Station and Kennedy Space Center sites

Commercial Space Transportation – Launch vehicle and launch operations owned by private organizations providing services to the NASA, DOD, and other customers with launch requirements

Launch-Window Sidereal Time (LWST) – "…local sidereal time (LST) for when the launch site is under the orbital plane (launch time)…Whenever the local sidereal time (at the launch site) equals the launch-window sidereal time (LST=LWST), the correct geometry exists to launch the spacecraft into the desired orbit" (Sellers, 2005, p.299).

The Gooch Factor – Retired Col. Gooch's determination that 70% of the scheduled launches actual happen at the Eastern and Western Ranges.

Acronyms

45th SW	45th Space Wing
AST	Aerospace Transportation
CCAFS	Cape Canaveral Air Force Station
COTS	Commercial Orbital Transportation Services
DMS	Delivery Management System
DOD	Department of Defense
DOT	Department of Transportation
DSS	Decision Support Systems
EELV	Evolved Expendable Launch Vehicle
FAA	Federal Aviation Administration
FPD	Fast Package Delivery
GEO	Geosynchronous Earth Orbit
ISS	International Space Station
KSC	Kennedy Space Center
LST	Local Sidereal Time
LWST	Launch-Window Sidereal Time NAS National Airspace System
NASA	National Aeronautics and Space Administration

NSRP	National Spacelift Requirements Process
NSRWG	National Spacelift Requirements Working Group
RLV	Reusable Launch Vehicle
ROPS	Range Operations
SATMS	Space and Air Traffic Management System
SLC	Space Launch Complex
SLMP	Space Launch Master Plan
SpaceX	Space Exploration Technologies Corporation
ULA	United Launch Alliance
U.S.	United States
USA	United States of America
U.S. DOT	United States Department of Transportation

REVIEW OF RELEVANT LITERATURE AND RESEARCH

Introduction

This study focused on the vertical launch schedule mean number of days between scheduled dates and the mean number of schedule dates per mission. CCAFS oversees diverse launch operations and is the conduit between the NASA and commercial launch and payload operator providers at the Eastern Range. Range scheduling at CCAFS coordinates all launch schedule requests and coordinates all launch date rescheduling for Cape Canaveral Spaceport. Some reasons for launch dates to change include launch system failure, payload issues, weather, and down range issues ranging from stray sea vessels to aircraft navigating in the designated airspace. Clearing the three dimensional airspace, the size of the Eastern Range is a remarkable task.

Managing Resources

Sellers states, "Mission managers and operators must carefully spend scare resources – time, money, and people – while monitoring the eternal tradeoffs among cost, schedule, and performance. The schedule critical factor is as follows:

1. To meet launch window requirements
2. To meet spacecraft position requirements to serve paying customers The longer the time factor on the ground, the more additional costs accrue" (2005, p. 365).

Future Aerospace Traffic Management

The FAA is "considering a 'Space and Air Traffic Management system (SATMS) that equitably supports both the evolving commercial space transportation industry and the mature and continuously growing aviation industry in a systematic, integrated manner. According to the FAA Aerospace Forecasts: Fiscal Years 2005-2016, this air traffic management system will include "…the people, infrastructure, policies, procedures, roles and regulations…under a single infrastructure" (U.S. Department of Transportation (DOT), FAA, Office of Aviation Policy and Plans, p.1). The issues and constraints of rescheduling a launch three weeks out or at the last minute will be an important part of the management systems decision support architecture. The U.S. DOT, FAA, Office of Aviation Policy and Plans specifies, "Launch and reentry plans…and launch/reentry window sizes, as important mission profile factors that impact the National Airspace System (NAS)" (U.S. DOT, FAA, Office of Policy and Plans, n.d., p. 10). The necessity to reschedule launches impacts the NAS and needs to be clearly understood to support future commercial space transportation activities.

Emerging Technologies

Emerging technologies that will support the present and future NAS include the following:

- Conflict Prediction/Resolution
- Precise Scheduling Capabilities
- Dynamic Airspace Configuration
- Enhanced Weather Prediction
- Trajectory Modeling
- Simulation
- Information Exchange/CDM tools
- Cockpit display of traffic

- Improved CNS
- Automation and Displays
- Decision Support Systems (DSS) System Performance Analysis Tools (U.S. DOT, FAA, Office of Policy and Plans, n.d., p.10)

The 2009 Commercial Space Transportation Forecasts report states, "Planners will need fast time analysis capability and… [operational]… contingency plans" (U.S. DOT, FAA, Office of Policy and Plans, n.d., p. 13-14).

Humankind is learning about mission planning and scheduling by researching the insect world around us. Mendham and Clarke, through their research, realized, "In a highly dynamic environment, plans may quickly become out of date requiring constant rescheduling or frequent re-planning" (2004, p.1).

Next Generation Spaceports

Brown speaks to, "…spaceports that operate more like airports in support of routine commercial space transportation (2001, p. 680)." The logistics between launch site operator, launch vehicle operator/payload owner, spacecraft insertion point, transfer- orbit/s, launch control operations, and ground station operations is an elaborate schedule engineering feat. "Range systems must be configured, tested, corrected, adjusted, and retested repeatedly for every launch, making turnaround time between missions long and expensive, particularly between missions involving different types of launch vehicles 2001, p. 680)". (Note: The Eastern Range (CCAFS) has experience turnaround times between 24-36 hours). Brown continues with concerns associated with extended delivery dates for "an automated planning and scheduling system for range facilities (2001, pp. 680-681)" speaking to technology obsolesce. After fifty one years of safely supporting the Nation's space launch needs, the national test ranges are confronted with the challenge to rapidly change, to accommodate the growing commercial launch industry, or face obsolescence.

The U.S. Air Force Space Command through its Range Integrated Product Team, "…addressed range turnaround times, scheduling systems, modernization programs, and range modernization (1998, p. 681)".

Brown expounds on The NextRange™ plan and states "Once complete, orbital traffic management and eventually interplanetary traffic management will be added (2001, p.682)".

Delivery of Cargo and People

One of the universal concepts for Reusable Launch Vehicles (RLVs) concerns scheduled and on demand delivery of cargo or people. Martin, J., Palmer, K., Chan, M. Karasi, A., and Glas, D. state, "Looking into the future for schedule and on-demand service requiring suborbital or orbital delivery, will require a delivery management system/s (DMS) that are continually updating the launch date and time requirements" (1998, p.1).

Martin, Palmer, et al. address the customer acceptable cost for fast package delivery (FPD) in relationship to the utility of time. They state, "As with the Fast Package Delivery System, customer acceptable cost for FPD is dependent on the margin of utility of time (1998, p. 1).

Time associated with horizontal processing, storage, and scheduling conflicts due to launch schedule slips or delays can create bottlenecking issues on and off the launch operations site. This impacts hardware, software, the human factor here on Earth, the point where the payload will be delivered, and the services it will be performing.

Commercial launch schedule delays may be translated by commercial launch customers into a punctuality issue. There is a list from airline operations that could prove to be a beneficial baseline for spaceport operations. Editors Butler and Keller published in the Handbook of Airline Operations, "The following outlines how to make punctuality a priority in the turnaround process and how to manage ongoing improvements in punctuality.

1. The biggest punctuality levers are to be found in streamlined communication and a tailor-made turnaround process.

2. A robust set of decision rules enables punctuality to be pursued realistically.
3. Top management securing the commitment of all concerned parties is imperative.
4. The only way to improve common processes in the future is through the committed teamwork of all concerned parties.
5. Improved punctuality requires a punctuality manager and an empowered team with the appropriate mandate.
6. Changing the mind-set and creating effective controls are prerequisites for anchoring improved punctuality in the organization. (2000, p.330)

Demand and Forecasting

According to the FAA Aerospace Forecasts, Fiscal Years 2005-2016, "…the GEO forecast also includes a realization factor that estimates the number of launches that will actually take place during the near-term portion of the model, to take into account the variance between forecasted demand and actual launches because of satellite and launch vehicle delays" (U.S. DOT, FAA, Office of Policy and Plans, n.d., p. 1X-7). The factors that affect forecasting include "satellite manufacturing delays, launch vehicle component problems, launch failure investigations, manifest issues, regulatory issues, satellite export compliance, FCC licensing, and changes in the business environment that alter or cancel satellite development plans (U.S. DOT, FAA, Office of Policy and Plans, n.d., p. 1X-9).

Operationally Responsive Space Components

"The commercial space sector was synergistic with the defense space sector because both were interested in lower prices and dependable launch schedules (Moorman, 2000, p.8). The 2004 Assured Access to Space Study, a 1994 Space Launch Master Plan (SLMP) follow on study, focused on "outlining the milestones, options, and alternatives to improve further the national security launch posture" (Moorman, 2000, p.8) and included the impact of schedule slips in the study's demand model. The actual number of flight rates is usually less than the original projections. The study included reliability, resiliency models, delineated Evolved

Expendable Launch Vehicle (EELV) options, and uncertainty, along with demand. The complexity associated with each factor, associated with each model, pointed to further analysis to define future viable options. What was determined was the EELV demand was much less than previously projected. What was not discussed was the rise in commercial payload owners choosing to launch their spacecraft from Russian or Chinese spaceports on foreign launch vehicles.

Launch Vehicle Management and Mission Planning

Launch vehicle management and mission planning evolve with each new mission program at the NASA, KSC. The Vehicle Management and Mission Planning System (VMMPS) proposed during the transitioning from the Apollo to the Shuttle program served as the system to meet the mission planning function requirements. Pruett and Bell state, “The use of this system will eliminate much redundancy and re-planning, shorten interface times between functions, and provide a means to evaluate unplanned events and modify schedules…flight operations must necessarily interface with all other elements of the program, methods must be developed to support these functions in an accurate, rapid, and economical manner…flight operations must be simplified and standardized without compromising mission success…tools must be developed that preclude the necessity for performing these functions (where possible) on a per mission basis (1973, p.1).”

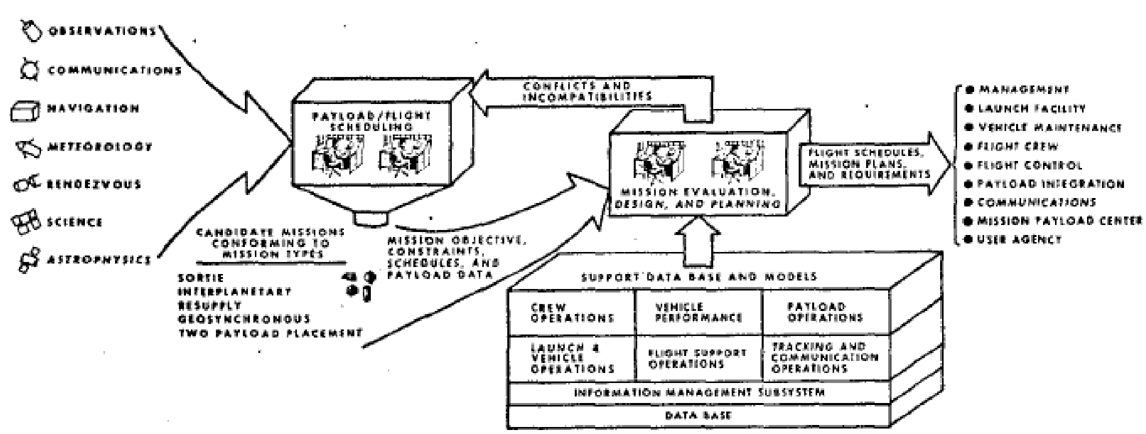


Figure 1. Basic VMMPS (Pruett and Bell, (1973) p.2)

Pruett and Bell cite four mission process requirements:

1. Missions should be standardized as much as possible
2. The multiplying effect of mission plan changes must be minimized
3. Organizational interfaces involved in mission design should be reduced
4. The amount of documentation required for each mission should be reduced

PHASES \ TYPES	MISSION TYPES A	MISSION TYPES B
1 (LAUNCH)	PROCEDURE 1.1 PROCEDURE 1.2 PROCEDURE 1.3 PROCEDURE 1.4	PROCEDURE 1.1 PROCEDURE 1.2
2 (OVERBURN INSERT)	NOT APPLICABLE	PROCEDURE 2.1
3 (ORBIT TRANSFER)	PROCEDURE 3.1 PROCEDURE 3.2	PROCEDURE 3.1 PROCEDURE 3.2
4 (DEPLOY)	NOT APPLICABLE	PROCEDURE 4.1 ⋮
5 (RENDEZVOUS)	PROCEDURE 5.1 PROCEDURE 5.2	NOT APPLICABLE
6 (ETC.)	⋮	⋮
7 ⋮		

Figure 2. Mission Types Composed of One or More Standard Mission Phases Each of Which Contains Numerous Procedures (Pruett & Bell, (1973) p. 3)

Nichols details a study that included all of the federal government agencies involved with spacelift in 1994, "The National Spacelift Requirements Process (NSRP) was an attempt to provide top-level government inter-agency consensus of the Nation's spacelift requirements" (1995, p. 1). As our Nation moves towards maturing commercial space transportation, the commercial launch vehicle providers together with the DOD and the NASA are redefining spacelift requirements using higher order technology and tailoring each mission to meet those requirements.

Schedule Dependability is defined in Nichols' paper's appendix as "The ability of the system to consistently launch, and land if required, when planned (1995, p. A-3)".

The National Spacelift Requirements Working Group developed Figure 3.

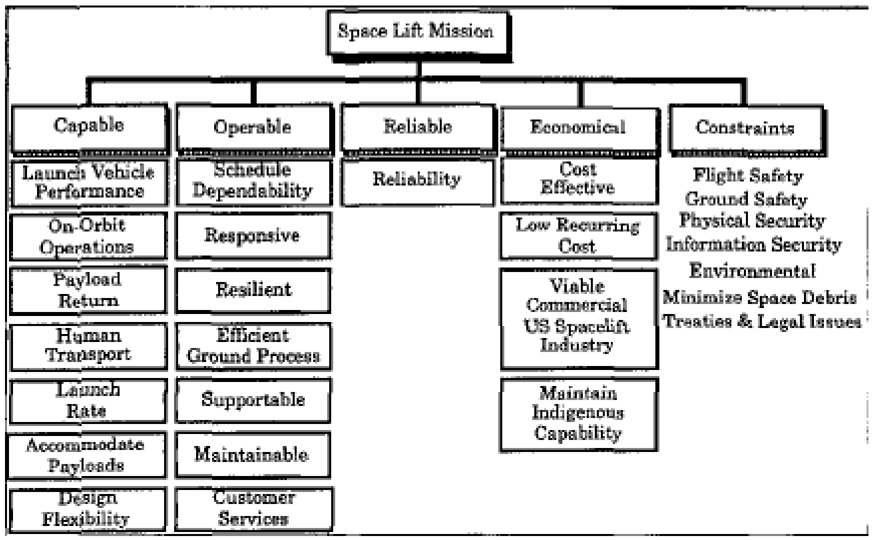


Figure 3. Characteristics of the Spacelift Mission (Nichols (1995) p.6)

As illustrated, Schedule Dependability ranks first under the Operable function. Understanding the mean number of days between initial launch and actual launch and associated reschedule dates will enhance the Nation's vertical launch capability at Cape Canaveral Spaceport to meet that requirement.

Summary

The mean number of days associated with the initial launch date and the actual launch date will assist in understanding and architecting future systems that will make launch turnaround times, resources allocations scheduling, and cost efficiencies and effectiveness a reality from National spaceports that launch payloads on commercial launch vehicles. Punctuality, as one of the critical factors in the launch segment of any suborbital/orbital mission, or beyond, will determine the operational success of our National spaceports.

Statement of the Hypothesis

Based on the review of literature and personal experience, the following four hypotheses were posited for this study.

Hypothesis 1: The mean number of days between initial launch date and actual launch date is more than three days.

Hypothesis 2: The mean number of launch scheduled dates to launch is more than three.

Hypothesis 3: The mean number of days between scheduled dates is more than three.

Hypothesis 4: The percentage of planned launches vs. actual launches at Cape Canaveral Spaceport is greater than seventy percent.

RESEARCH METHODS

Research Design

This is a descriptive, quantitative research design based on historical hard data derived from the scheduled launch dates from the Cape Canaveral Spaceport (as logged by Spaceflight Now) and includes missions with actual scheduled launch dates within the 2008 and 2009 time frame.

Population

The sample data was derived from missions where the actual scheduled launch date fell in the 2008 and 2009 time frame. There are some missions that started with an initial launch date in the 2007 time frame and concluded with a 2008 actual launch date. The missions beginning with an initial launch date in 2009 without completion of an actual launch date in 2009 are only included in the planned vs. actual percentage analysis.

Sources of Data

The Spaceflight Now website has capture launch schedule data from 2004 to present. The mission launch dates culminating in an actual launch in the 2008 and 2009 time frame were included in the data collected for this research.

Treatment of the Data and Procedures

The hard data was collected from Spaceflight Now website's Launch Schedule Log. The missions were identified as Mission 1, Mission 2…through Mission 24 to keep the focus on the scheduled launch dates per mission, time in days between scheduled launch dates per mission, and time in days from initial scheduled launch date to the actual launch date. Missions 25-27 were used for the planned vs. actual percentage analysis only.

The initial scheduled launch date, reschedule date/s, and the actual launch date were entered into a Mission/Day Excel spreadsheet sequentially. Then, number of missions that launched on the initial launch date was visually determined from the Mission/Day spreadsheet.

The remaining data provided the framework to determine the number of days between the initial and actual launch date and between each rescheduled launch date. The number of rescheduled launch dates after the initial date and the number of rescheduled launch dates between the initial and actual launch date were then calculated. The following descriptive statistics were then calculated based on the sample data. Each of the four calculations corresponds to one of the sub problems listed in Chapter I.

1. Estimate the mean number of days between the initial launch date and the actual launch date.
2. Estimate the mean number of scheduled dates to launch per mission.
3. Estimate the mean number of days between the scheduled launch dates per mission.
4. Investigate the percentage of planned scheduled launches vs. actual launches at Cape Canaveral Spaceport

A 95% confidence interval was calculated as a population estimate for descriptive statistics 1. - 3.

Hypothesis 1 states that the mean number of days between initial launch date and actual launch is more than three. A test for means, at the 0.05 level of significance, to test the null hypothesis that the mean number of days between initial scheduled and actual launch dates is more than three was initially planned. If the null was rejected and the sample mean was greater than three, the research hypothesis would have been supported.

Hypothesis 2 states the number of scheduled launch dates per mission is greater than three was planned initially. A test for means, at the 0.05 level of significance, to test the null hypothesis that the mean number of scheduled launch dates per mission is more than three. If the null was rejected and the sample mean was greater than three, the research hypothesis would have been supported.

Hypothesis 3 states that the mean number of days between scheduled launch dates is more than three. A test for means, at the 0.05 level of significance, to test the null hypothesis that the mean number of days between each scheduled launch date per mission is more than three. If the null was rejected and the sample mean was greater than three, the research hypothesis would have been supported.

Hypothesis 4 states that the percentage of planned launches vs. actual launches at Cape Canaveral Spaceport is greater than seventy percent. The Gooch Factor (referencing the percentage of predicted vs. actual launches from CCAFS and Vandenberg Air Force Base) states, "The actual number of flight rates is usually less than the original predictions…that the Nation only launches approximately 70 percent what it plans to launch (Moorman, 2006, p. 9). The number of "projected launch" missions scheduled for 2008 and 2009 (as derived from the Spaceflight Now Launch log date) versus actual launched missions, and the total number of launches was calculated. A test of proportions of Mean-One Sample was conducted, at .05 Level of Significance. If the null is rejected, the percentage of missions launched as planned will be seventy percent or less. If the results fail to reject the null, the evidence will be sufficient to conclude the planned vs. actual launch percentage is greater than seventy percent for actual launches within the 2008-2009 timeframe at Cape Canaveral Spaceport.

RESULTS

The following results utilized the Table 1 Data Columns and are derived from the Statdisk Descriptive Statistical and Confidence Intervals analysis for sub problems 1-3 and Hypothesis Testing, Proportions One-Mean Sample for sub problem 4.

Table 1. *Statdisk Data Columns*

MISSION	MEAN # of Days Between Initial & Actual	MEAN # of Days Between Initial & Rescheduled Dates	MEAN Number of Scheduled/Rescheduled Dates Per Mission
1	133	17	8
2	103	34	3
3	2	1	1
4	319	64	5
5	37	19	2
6	248	28	9
7	58	15	4
8	358	30	13
9	90	30	3
10	129	22	7
11	267	89	3
12	224	27	9
13	279	47	6
14	233	26	9
15	440	40	11
16	61	12	5
17	279	140	2
18	55	6	9
19	53	27	2
20	670	48	14
21	115	29	4
22	4	4	0
23	40	20	2
24	66	13	5

Hypothesis 1 and Sub problem 1

Hypothesis 1 states that the mean number of days between initial launch date and actual launch, or the number of days between scheduled dates, is more than three.

Sample Size, n:	24
Mean:	177.625
St Dev, s:	160.7966

Figure 4. Statdisk Descriptive Statistics Problem 1

A 95% confidence level was calculated as an estimate, see Figure 5. The 95% confidence interval was (110,245). Therefore, the null is rejected and the population mean is greater than three, supporting the research hypothesis.

95% Confident the population mean is within the range:

109.7002 < mean <245.4998

Figure 5. Statdisk Confidence Intervals for Number of Days Problem 1

Hypothesis 2 and Sub problem 2

Hypothesis 2 states that the mean number of launch schedule dates is more than three. The analysis indicates that the mean number of launch schedule dates is 6 dates per mission.

Sample Size, n:	24
Mean:	5.666
St Dev, s:	3.8410

Figure 6. Descriptive Statistics Problem 2

A 95% confidence level was calculated as an estimate, see Figure 7. The 95% confidence interval was (4, 8). Therefore, the null is rejected and the population mean is greater than three, supporting the research hypothesis.

95% Confident the population mean is within the range:
4.31095 < mean <7.68905

Figure 7. Confidence Intervals for Number of Days Problem 2

Hypothesis 3 and Sub problem 3

Hypothesis 3 states that the mean number of days between rescheduled dates is more than three. The analysis indicates that the mean number of days between rescheduled dates is 33 days.

Sample Size, n: 24
Mean: 32.833
St Dev, s: 29.9980

Figure 8. Statdisk Descriptive Statistics Problem 3

A 95% confidence level was calculated as an estimate, see Figure 7. The 95% confidence interval was (20, 45). Therefore, the null is rejected and the population mean is greater than three, supporting the research hypothesis.

95% Confident the population mean is within the range:
20.13212 < mean <45.46788

Figure 9 Statdisk Confidence Intervals for Number of Days Problem 3

Hypothesis 4 Sub problem 4

Hypothesis 4 states that the percentage of planned launches vs. actual launches at Cape Canaveral Spaceport is greater than seventy percent.

The analysis for each year and for the combined years, 2008-2009, result in an eighty-eight percent (88%) launch rate for missions scheduled in 2008, an eighty-nine percent (89%) launch rate for missions scheduled in 2009, and an eighty-nine percent (89%) launch rate for missions with scheduled launches in the 2008-2009 timeframe.

Claim: p > p(hyp)

Sample proportion: 0.8888889

Test Statistic, z: 2.1418

Critical z: 1.6449

P-Value: 0.0161

90% Confidence interval:

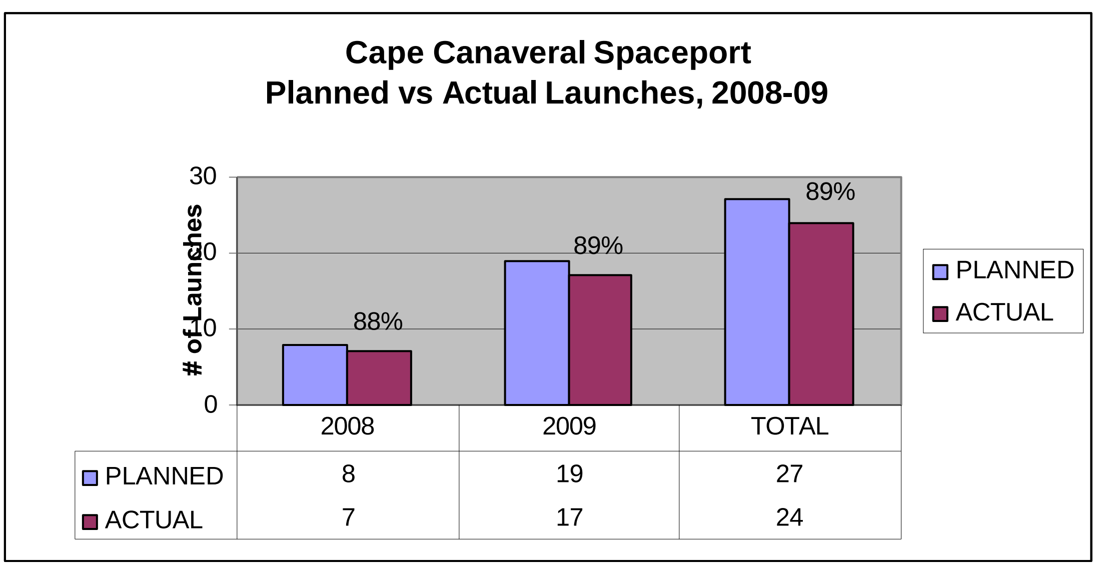
0.7894062 < p < 0.9883716

Reject the Null Hypothesis

Sample provides evidence to support the claim

Figure 10. Statdisk Hypothesis Testing, One-Mean Sample Problem 4

Table 2. *Planned Versus Actual Launches, 2008-2009*



DISCUSSION

The researcher's '3 days' as a mean value for launch scheduling humans, goods, and services into orbit or beyond was a civilian, outside-the- launch- scheduling realm was a 'best' guess. The 70% Gooch Factor associated with Hypothesis 4 and Sub problem 4 was referenced from the literature review. To the researcher's knowledge this is the first time research has been conducted on the launch schedule dates at the Cape Canaveral Spaceport. The reason for this data collection was to determine the existing parameters associated with launch schedules at both the KSC and the CCAFS to make the proper assessments concerning scheduling future commercial launch and payload resource allocations.

Hypothesis 1 and Sub problem 1

A 95% confidence level was calculated as an estimate. The data used in the calculation is summarized in Table 1. The 95% confidence interval is (110, 245). Therefore, the null is rejected and the sample mean is greater than three, supporting the research hypothesis. The best estimate was calculated at 178 days. The researcher is 95% confident that the number of days between an initial and actual launch date is no less than 110 and no more than 245. The confidence interval for the number of days between the initial and actual launch date (110,245) is a wide interval because of the large variance (standard deviation). The actual range of is 2-670 days. Remember each mission was analyzed only by schedule dates and in days. While collecting the data, the researcher discerned the variety of timelines had no apparent commonality.

Hypothesis 2 and Sub problem 2

A 95% confidence level was calculated as an estimate, see Figure 9. The 95% confidence interval was (4, 8). Therefore, the null is rejected and the population mean is greater than three, supporting the research hypothesis.

The best estimate was calculated at 6 days. The researcher is 95% confident that the number of reschedule dates per mission is no less than 4 and no more than 8. The mean of 6 reschedule dates (approximately one week) is approximately 2 times greater than what Hypothesis I states. The actual range of is 0-14 days. Remember each mission was analyzed only by schedule dates and in days. While collecting the data, the researcher discerned the variety of timelines had no apparent commonality.

Hypothesis 3 and Sub problem 3

A 95% confidence level was calculated as an estimate, see Figure 7. The 95% confidence interval was (20, 45). Therefore, the null is rejected and the population mean is greater than three, supporting the research hypothesis The analysis indicates that the mean number of days between rescheduled dates is 33 days.

Hypothesis 4 and Sub problem 4

The Gooch Factor speaks to 70% of predicted launches, actually launching from the Eastern and Western Ranges in the USA, analyzing a 10 year time frame. Due to the small sample size of only 2 years at the KSC and CCAFS (Eastern Range) the data is not comparable, but the 70% percentage was noted as a reference point and used in the Hypothesis 4 and Sub problem 4. The percentage of predicted launches that actually launched from the Cape Canaveral Spaceport in 2008 was 88% and in 2009 89%. For the 2008-2009 combined timeframe the percentage was 89%. The proportions test illustrates the percentage of actual launches is significantly higher than the Gooch factor of 70%. This researcher is 95% confident of that conclusion.

CONCLUSIONS

Major conclusions based on this research are the following (by hypothesis):

1. The average number of days between the initial and actual launch dates is between 110 and 245 days.
2. The average number of scheduled launch dates per mission is between 4-8 days.

3. The average number of days between scheduled launch dates per mission is 20-45 days.
4. The percentage of actual launches is higher than the Gooch factor implied. Each hypothesis in this study was supported by the research analysis using

Descriptive Statistics and Confidence Intervals, Mean-One Sample for Hypothesis 1-3 and Hypothesis Testing, Proportion – One Sample for Hypothesis 4. The data collection and statistical analysis results validate the long timelines associated with the aerospace industry and the iterative nature of launch scheduling/rescheduling at Cape Canaveral Spaceport. Of the 24 missions that launch in the 2008-2009 timeframe, not one mission launched without a reschedule date.

The mean number of days between the initial scheduled and actual launch dates of 178 days (approximately one half of a year) is a significant factor in that it is approximately 60 times greater than what the research hypothesized, as an outsider to vertical launch scheduling. The longer timeline validates the unique attributes associated with vertical launch space transportation. The longest timeline of 670 days to the shortest timeline of 2 days illustrates the chasm of time between the two extremes. These timeline variations clearly separate vertical launch vehicle space transportation from traditional modes of transportation.

The mean number of scheduled/rescheduled dates per mission is 6 schedule/reschedule dates. These numbers are the number of reschedule iterations that should be considered when planning and creating forecasting models. This data illustrates the number of times all schedulers could conceivably be required to reschedule a launch. Two of the launches have 0 scheduled dates between the Initial and Actual Date. These numbers are the number of iterations between the initial launch date and the actual launch date that should be considered when planning and creating forecasting models. This data illustrates the number of times all schedulers could conceivably be required to reschedule a launch from shortest to longest case scenarios, as represented within the 2008-2009 timeframe.

The mean number of days between the initial scheduled launch date and each subsequent reschedule date per mission is 33 days (approximately a month), with the range of 1-140 days. The mean and range values provide baselines for monthly demand on processing and storage facilities for launch vehicles stages and payloads, as well as launch pad coordination for pads serving multiple launch vehicle customers.

The planned vs. actual launch percentage results of greater than 70% indicate a positive trend, eighty-nine percent (89%) for all actual launches from Cape Canaveral Spaceport within the 2008-2009 time frame.

RECOMMENDATIONS

This research is only the beginning of constructive research focused on determining the function of launch scheduling for commercial space transportation. Similar to aviation moving from government control to commercial control (with government law, rules and regulation, and oversight) commercial space launch research is wide open. Someone should conduct similar research using the KSC and CCAFS historical data for launch scheduling. This research showed commercial launch and payload customers should expect reschedule dates between the initial and actual launch dates.

Reschedule dates are to be expected and crews and effected operation schedulers should build in flex-time to compensate for other contracted mission reschedule dates. Spaceport operations teams, resource allocations schedulers, and spectators need to plan accordingly. Cost research could drive innovative spaceport processes development. Space transportation should not be thought of in the same sense as Earth modes of transportation. Multimodal hub interface research to support future planning costs, collaborative modernization and enhancement of existing infrastructure, air traffic control scheduling and costs, highway traffic impact, shipping traffic scheduling and costs, geophysical impacts to launch scheduling, and researching the feasibility of a multi-governmental agency decision management system to support in coordinating all national launch activities should be considered. There are many opportunities for further research concerning the scheduling of space transportation launching from the Cape Canaveral Spaceport. No other location on Earth has the diversity of legacy launch vehicles and payloads, with supporting infrastructure and trained personnel. When the next solar storm hits the Earth's assets in space, there could be a marked increase in launch and payload demand. Future research should be conducted addressing the optimal launch scheduling capacity employing the current assets at the Cape Canaveral Spaceport and how that capacity could be increased to meet the demand for payload delivery to re-establish space technology services. The scheduling of human spaceflight, goods and services to support commercial requirements versus the NASA and DoD requirements opens many avenues for future research as well.

This research could be utilized as a baseline for future research to determine what direction launch scheduling at the Cape Canaveral Spaceport is headed. But for now, the results can be used to inform customers and forecast future scheduling parameters, to keep the costs of operating launch pads, payload processing facilities, crews, and supporting activities in check, maximize resource allocations.

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