Skill Acquisition and Decay in Aircraft Carrier Landings

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ABSTRACT

Rapidly advancing aircraft technology is making it necessary for Naval Aviation to reassess training requirements for safe and expeditious aircraft carrier landings. Specifically, the effects of the Precision Landing Mode in the F-35C and recently in the F/A-18E/F raises questions about the volume and types of training necessary for aviator Carrier Qualification (CQ). The Landing Signal Officer (LSO) community is analyzing historical Field Carrier Landing Practice (FCLP) and carrier aircraft landing data to better understand the nature of skill acquisition and decay. Specific attention is focusing on the analysis of the number of FCLPs for aviators to gain and maintain proficiency in preparation for CQ. This paper presents the results of this analysis.

In direct support, BGI constructed a database detailing nearly one million LSO-graded landings, dating from 1997 to 2017, from records provided by the U.S. Navy LSO School at Naval Air Station Oceana, VA. Through the analysis of these records in a database, using natural language processing and machine learning tools, BGI identified trends that can help drive CQ training requirements. As an example, skill acquisition rates as a function of number of landings are very similar across platforms, including all F/A-18 and E-2 series. Similarly, skill decay rates as a function of time elapsed since last carrier landing are also similar, and maximum skill decay appears to occur as soon as forty days after an aviator's last carrier landing. Furthermore, BGI's analysis shows the magnitude of skill acquisition in the T-45 over one hundred FCLP passes is significantly greater than for other platforms.

This analysis is relevant to Naval Aviation CQ training. As consideration is given to whether the T-45 replacement should be carrier-capable or not and whether the number of required FCLPs can be reduced without adversely affecting safe and expeditious carrier landing performance, this analysis will enable data-driven decisions to be made.

ABOUT THE AUTHORS

Dr. Rocco Panella Dr. Rocco Panella is a Data Scientist with 8 years of industrial experience building automated, machine-learning-driven quality control systems. His work at BGI has included developing several applications utilizing machine learning for the LSO community. These include a handwriting transcription program for handwritten LSO notes, and the LSO Data Analysis Toolkit (DAT), which builds visuals of aircrew carrier passes using NLP on LSO comments. Prior to working with BGI, he was the owner of Intel Corp.'s substrate manufacturing computer vision systems as well as owning several reporting systems for factory health. He is currently a Data Analytics Engineer working on data warehousing for Nestlé.

CDR Bryan C. Roberts USN (ret.) graduated from the U.S. Naval Academy in 1995, and was designated a Naval Aviator in September 1998. All assignments during his 25-year career were flying tours. He accumulated more than 3,500 flights hours and 830 arrested landings in all models of the F-14 and F/A-18. CDR Roberts' pinnacle tour was the Officer in Charge of the U.S Navy LSO School from 2014-2018. During his tenure as the senior cognizant U.S. Navy LSO, he directly oversaw multiple historic firsts, including waving the first landings of the F-35C, first FA-18 Precision Landing Mode (PLM) shipboard landings, X-47B UCAS landings, and the first landings aboard the USS FORD. CDR Roberts is the only LSO in the history of the Navy to have waved every aircraft from F-14A through F-35C onboard every U.S. Navy aircraft carrier from CV-67 through CVN-78.

Marissa Utterberg is a software developer and data scientist with professional and volunteer experience in math education and training. She holds an undergraduate degree in mathematics and a graduate certificate in Data Based Decision Making. She is the founder of Cleveland PyLadies and co-organizer of Django Girls of Cleveland, and is currently an Associate Software Engineer for DialogTech.

OVERVIEW

Landing aboard an aircraft carrier is widely recognized as one of the most challenging tasks in all of aviation, requiring hundreds of dedicated training sorties, including Field Carrier Landing Practice (FCLP), in order to make a pilot safe and predictable in the carrier environment. Every FCLP and carrier landing is graded by a Landing Signal Officer (LSO) (Figure 1). Pilot landing performance parameters are entered into a database system known as the Automated Performance Assessment and Remedial Training System (APARTS), a disparate collection of databases maintained by the LSO community designed to identify overall pilot trends. LSO's spend a significant amount of time manually analyzing these trends to identify individual pilot skill deficiencies in an attempt to eradicate negative trends and improve overall predictability and safe performance.

Figure 1. LSO communicating with pilot during carrier landing (Reference 7)

FCLPs are a key component of Carrier Qualification (CQ) training and lower the risk associated with landing aboard an aircraft carrier (Reference 8). For Undergraduate CQ, FCLPs are the first time Student Naval Aviators (SNAs) directly and repeatedly experience the demanding task loading of carrier-type landings (Figure 2). As such, a significant amount of training hours are spent on FCLPs. However, FCLPs are costly to conduct in terms of the actual cost of operating a navy aircraft to the associated environmental impacts. As Naval Aviation is under ever increasing financial pressure to justify every expense, and often subject to legal pressure, (References 1, 6), Naval Aviation leaders must always quantify the value of FCLPs. As described above, the LSO community has historically used APARTS for CQ performance reporting and short-term trend analysis but now seek additional insights that can be mined from archival APARTS data to address FCLP efficacy and embarked currency requirements.

Naval Aviation leadership is looking for ways to train pilots more efficiently and effectively by leveraging learning points derived from APARTS data collection and analysis. The relatively recent introduction of Precision Landing Modes (PLM) has caused a reassessment of requirements for carrier landing training, qualification, and currency. PLM marks a fundamental change in how pilots land aboard aircraft carriers by vastly simplifying the difficult task of precisely and repeatedly flying extraordinarily tight parameters required for safe landings (Reference 10). However, since some older aircraft types (i.e. E-2 Hawkeye) will never have PLM capability, the Naval Aviation Enterprise (NAE) must also understand any distinct levels of training required for different types of aircraft.

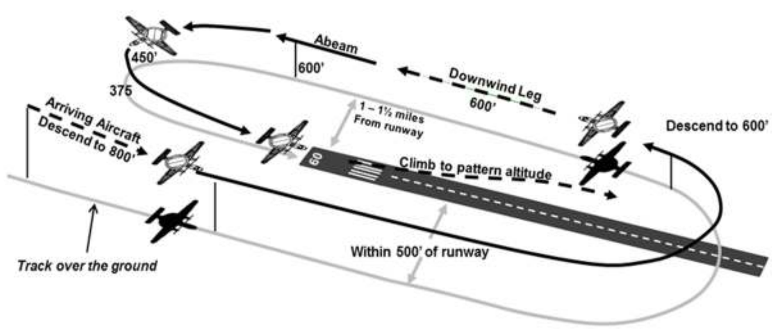

Figure 2. FCLP Pattern (Reference 9)

Recent Sea Change

As of December 2020, the entire F/A-18E/F fleet has been fitted with software and hardware that make PLM a fully-redundant system, negating any need for pilots to train in "legacy" traditional manual landing modes. Fleet Replacement Squadron (FRS) student aviators now conduct all training for CQ in these enhanced modes (Reference 2) and FCLP reduction is currently being implemented given enhanced PLM capability.

Occurring in parallel with full PLM integration has been the Navy's efforts to identify the next-generation trainer aircraft to replace the T-45C Goshawk, which students use for all Undergraduate Flight Training, including Initial CQ. Consideration is being given to whether the next trainer aircraft (which is planned to be a Joint USAF-USN trainer) has a requirement to be carrier-capable (Reference 3). Furthermore, the Chief of Naval Air Training (CNATRA) is implementing a "CQ Experiment" to assess how SNAs who have never landed on an aircraft carrier perform in the F/A-18 with no prior CQ baseline skill acquisition. The results of this experiment will drive decisions for future trainer aircraft requirements, as well as shape the syllabus in the Naval Aviation training pipeline.

BGI has conducted a detailed analysis of an aggregated APARTS database and presents preliminary findings in this paper that highlight the importance of early land-based training and the rate of pilot skill decay given time lapse between carrier landings. This research is even more relevant now based on the focus to make data-driven decisions to further refine FCLP requirements and the future of CQ training given the potential for the next trainer aircraft to not be carrier-capable.

Problem Statements

The LSO community approached BGI with an interest in mining APARTS archives for insight into operational priorities. Operational Analysts (OAs) assisted BGI in developing the following research questions:

- P.S.1) Was there measurable skill acquisition during FCLP training periods before the introduction of PLM?
- P.S.2) What risks are involved in reducing the number of FCLPs required or recommended for naval aviators at various career stages?
- P.S.3) Was there a significant difference in the skill acquisition of E-2 pilots and F/A-18 pilots before the introduction of PLM to the latter platform?
- P.S.4) What is the expected effect of PLM on carrier landing skill acquisition?
- P.S.5) How quickly did carrier landing skill decay before the introduction of PLM?
- P.S.6) What is the expected effect of PLM on skill decay in naval aviators?
- P.S.7) Can advanced analysis of LSO comments proactively identify bad flight habits before a dangerous pass occurs?
- P.S.8) Will PLM landings mask behaviors that could lead to dangerous landings?

DESIGN AND PROCEDURE

Framework

This study follows the Epicycles of Analysis model suggested by Roger Peng (Reference 4), in which analysts test and refine hypotheses in an iterative fashion. Peng's epicycle consists of iterating through the following steps:

1) Setting expectations
2) Collecting and analyzing data
3) Revising expectations or fixing data based on results

BGI performed this epicycle of analysis across all core analysis activities:

1) Stating and refining questions
2) Exploratory data analysis
3) Model building
4) Interpreting results
5) Communicating results

A benefit of this approach was additional questions were identified as the research team learned from the data set.

Data Sources

The primary data source for this analysis was a collection of exports from disparate instances of the APARTS application, with dates ranging from 1997 to 2017. These exports typically present as separate txt or csv files for the two main tables in the local APARTS database:

- PASS: contains data for a recovery session
- SUB: contains data for individual approaches within a recovery

Automating resilient re-joins of these disparate tables once separated became the first engineering challenge, as exported files did not contain unique keys on which to link SUB records with their corresponding recovery data. The initial solution for this was to link records based on fields present in both tables: date-time and location.

BGI received a small number of incomplete exports that included files for the SUB table without corresponding files for the PASS table. For these records, BGI inferred the pass type (FCLP versus carrier landing) from the geographic location and calculated whether the pass was a day or night landing based on time of day and month of year. However, BGI was unable to infer specific Events for these records. In addition, BGI identified that Events were unrecorded for 20% of recovery records in the PASS tables received.

Upon performing initial analyses on this joined data set, BGI discovered pilot identification across squadrons to be a major engineering challenge. The problem of assigning unique pilot identifiers to enable long-term trend analysis is a known issue in the APARTS paradigm, as evidenced by an internal memorandum sent in 2013 regarding data corruption. Forthcoming versions of the working database system for storing carrier-type landing data (SHiPARTS) should address this issue, but archival APARTS data will not benefit from unique pilot identifiers. Researchers must keep these concerns in mind in any study of APARTS data.

Automated Comment Vectorization

In order to include qualitative LSO feedback in the analyses, BGI worked with LSO subject-matter experts to quantify individual comments captured in standard LSO shorthand. Taking comment fields as parsed into distinct categories by the APARTS application, BGI assigned values based on the direction (i.e. positive for high, negative for low) and magnitude (i.e. *2 for "_comment_" and *0.5 for "(comment)") indicated by comment meanings. BGI knows from LSO feedback that the APARTS comment parsing algorithm contained flaws that did not account for human data entry tendencies. For example, APARTS incorrectly parsed (H.OSX) as "a little holdoff on settle on start", when any LSO would know that it means the same as (HOSX): "a little high overshooting start." SHiPARTS will address such issues, but future researchers may choose to spend additional time to create a custom comment parser for archival APARTS data. Representing each phrase as a one-dimensional array (vector) of comment values allowed BGI to apply many quantitative analyses and visualization methods, such as the plot series shown in Figure 3.

BGI found evidence of similar vectorization algorithms in the APARTS application based on the availability of bar charts in the trend analysis report. Neil C. Rowe also followed a similar vectorization process in Automated Trend Analysis for Navy-Carrier Landing Attempts (Reference 5), though this analysis mainly focused on comment vector frequencies. The data set for Rowe's study pre-dates the 2013 APARTS standardization memorandum.

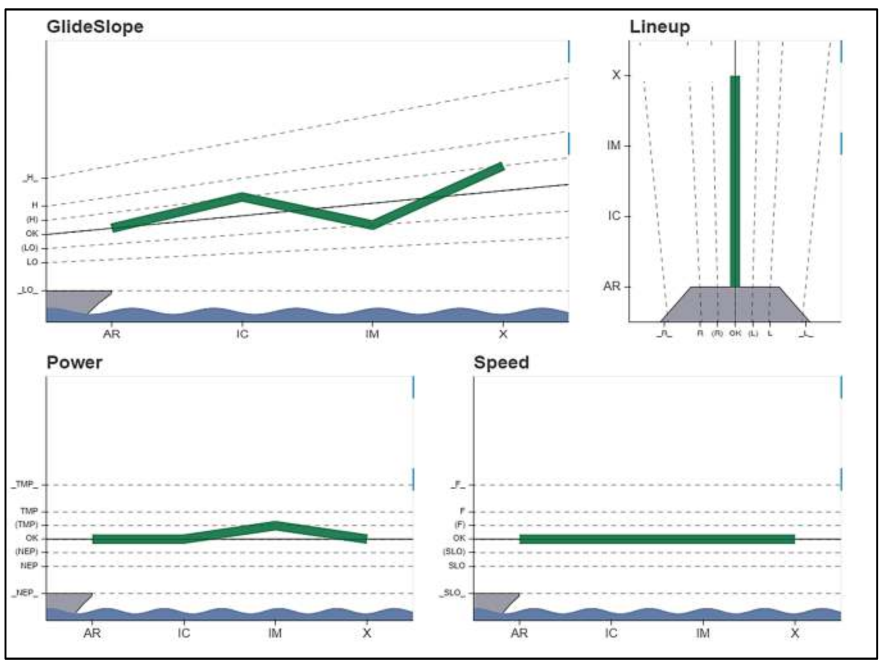

Figure 3. Plot of APARTS data (LSO captured comments) using its vector form. For the upper left and two bottom visuals, the ramp is in the bottom left corner of the plot, and the line represents the path of the title variable. For the upper right visual, the ramp is at the bottom of the plot, and the visual is a god's-eye view.

Manual Pilot History Reconstruction

Even after receiving pilot identification keys, BGI found that a given pilot's records might be found under different names (ie LASTFIRST827, LASTFIR827, LAST827, LAS827) and formats (ie LAST,FIRST vs LAST, FIRST vs LASTFIRST vs LAST) over time and across squadrons. BGI also found that each such variation was coded as a different pilot in the original de-identified sets we received (ie LAST, F. coded as 123; LAST, F coded as 234). Because of this, BGI could not confidently say that a pilot's first record under a particular name variation was truly their first landing attempt. Though the initial appearance was that our subsets contained 950,829 non-duplicated records for 6,935 pilots, the uniqueness of those pilots was questionable.

After auditing this dataset, BGI developed a training analysis subset containing data ranging from 2004 to 2015. Dates outside of this range appear in fewer than 10,000 records per year across the larger skill acquisition and decay analysis subsets. Skill acquisition and skill decay results use a dataset consisting of 570,698 records from 1,713 manually-identified pilots. Training and comment analysis results use a subset of this, consisting of 50,585 records from 125 pilots that met minimum FCLP and platform criteria.

RESULTS

Training

In light of the rapid adoption of PLM, the Navy is interested in understanding if the current number of FCLPs performed by aviators are required to safely train for arrested carrier landings. The training that aviators undergo in the T-45 does not utilize PLM, so they are specifically interested in understanding if these FCLPs have a significant effect on later performance.

Correlation Analysis

In looking to measure the effect of FCLP training on carrier performance, BGI began with correlation analyses of mean normalized landing Grade Point Average (GPA) for each group of interest. Each pilot in the available subset is given two summative scores: one for the potential predictive feature (mean normalized GPA for their final 10 FCLP of a given platform) and one for the potential prediction feature (mean normalized GPA for their first 10 CQ passes of a given platform). Every point then represents a single pilot's aggregate summary.

In the following plot series, the value included in the plot title indicates the strength of the correlation plotted, with 1.0 being perfect positive correlation and -1.0 being a perfect negative correlation. Strong correlations do not necessitate a cause-effect relationship, but they allow us to use potential predictor group performance to reasonably guess future performance of the potential prediction group.

Comparing the last 20 T-45 FCLPs with the first 20 passes of Undergraduate CQ (Figure 4), BGI observed very little evidence supporting a predictive relationship between FCLP and carrier performance in the T-45. The correlation strength is approximately 0.29 for the 184 pilots in the APARTS subset with sufficient data and reasonable confidence that the pilots moved on with advanced aircraft

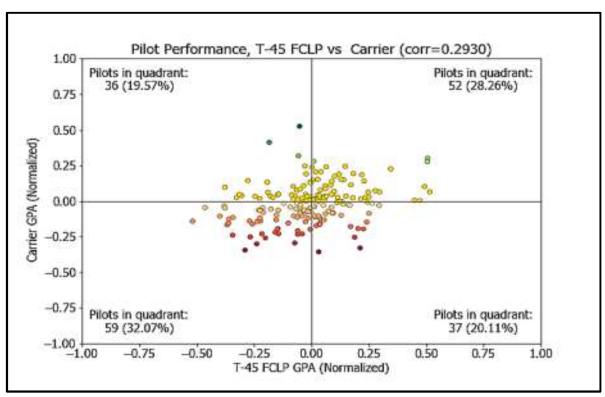

Figure 4. T-45 predictability – FCLP vs Carrier

training. Human intuition can visualize a positive correlation starting to form upon casual inspection of the plotted results, but the mathematical ability to make predictions about Undergraduate CQ starting GPA based on T-45 FCLP ending GPA is weak for the given subset.

Similarly, the last 20 F/A-18 FRS FCLP and the first 20 passes of Initial CQ (Figure 5) show little evidence supporting a predictive relationship between FCLPs and carrier performance in F/A-18 FRS. The correlation strength is approximately 0.18 for the 136 pilots with sufficient F/A-18 data and reasonable confidence that T-45 data for the pilots exists in this APARTS subset.

The final comparison is between T-45 FCLP and F/A-18 FRS Initial CQ (Figure 6). The 134 pilots with sufficient data in both of these stages have a correlation strength of approximately 0.11, the lowest of all groups compared. This suggests T-45 FCLP performance is a poor predictor of Initial CQ performance. This is an indication that GPA for a pilot's ending FCLPs are not mathematical predictors of pilot performance in early CQ passes, especially across platforms. Considering the amount of time between T-45 FCLPs and Initial CQ in the F/A-18, the variety of training exercises contributing to skill transfer conducted in the interim, and the instructor insight that GPA does not capture, it is not surprising that the data reveal no clear correlation in this context. T-45 FCLPs and Undergraduate CQ have the highest correlation out of all scenarios included, though the prediction factor is still weak. Rather than trying to use FCLP data to predict carrier performance, especially across platforms, BGI turned to a value-added perspective in addressing the question of FCLP valuation.

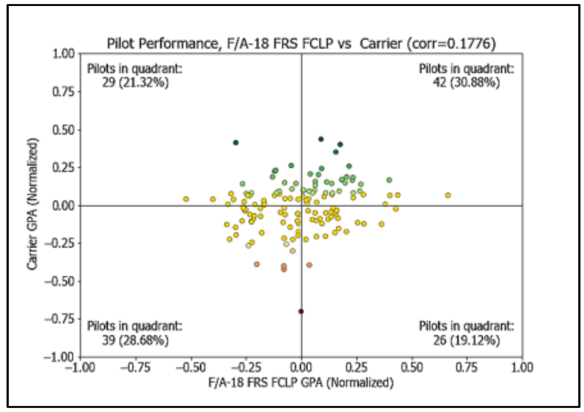

Figure 5. F/A-18 FRS predictability – FCLP vs Carrier

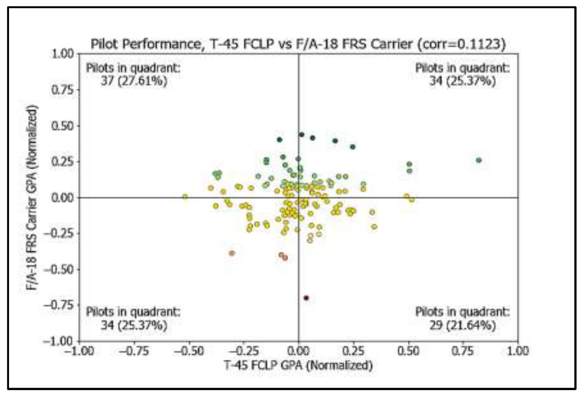

Figure 6. Cross-platform predictability – T-45 FCLP vs F/A-18 FRS carrier performance

GPA Progression

Since a single aggregate summary does not appear to capture pilot growth during training, BGI looked at performance trends within each stage. Looking to compare FCLPs in T-45 training with FCLPs in F/A-18 FRS, BGI tracked the normalized GPA as students accumulate repetitions (Figure 7).

With this norm-referenced metric for skill acquisition, BGI observed that T-45 pilots begin well below their training average and steadily improve as they accumulate FCLPs. F/A-18 pilots appear to start FRS FCLPs slightly above their training average and show similar growth rates.

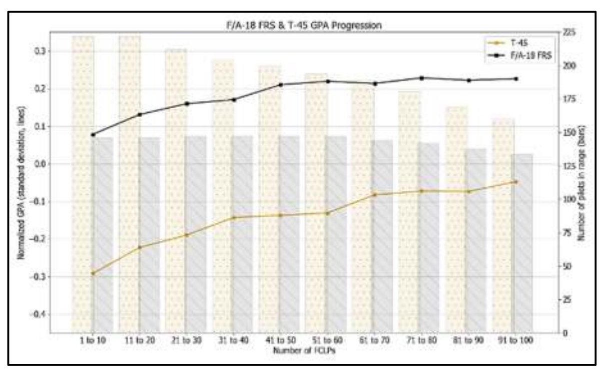

Figure 7. Normalized GPA vs number of FCLPs, T-45 and F/A-18 (FRS)

As in the correlation analyses, BGI was interested in the relationship between FCLP and the first 20 passes of CQ. In Figure 8, it appears that F/A-18 FRS pilots enter Initial CQ slightly below their mean training GPA and do not reach this mean GPA level within the first 20 passes. BGI observed similar growth rates for T-45 pilots during the first 20 passes of Undergraduate CQ occurring further below mean GPA levels.

LSOs repeatedly communicated the difficulty of performing nighttime landings, so BGI was interested in any differences or similarities between training outcomes for days and nights. Noting that T-45 night FCLPs typically occur at or near the end of the syllabus, we see no difference between the plots in Figure 9 until the 51-60 bin for these students. The general trend of steady improvement is clear for T-45 day FCLPs and present for F/A-18 FRS FCLPs, if somewhat less smooth.

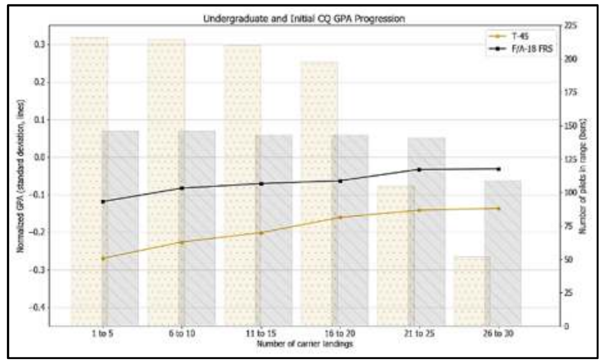

Figure 8. Normalized GPA vs number of carrier landings, early Undergraduate and Initial CQ.

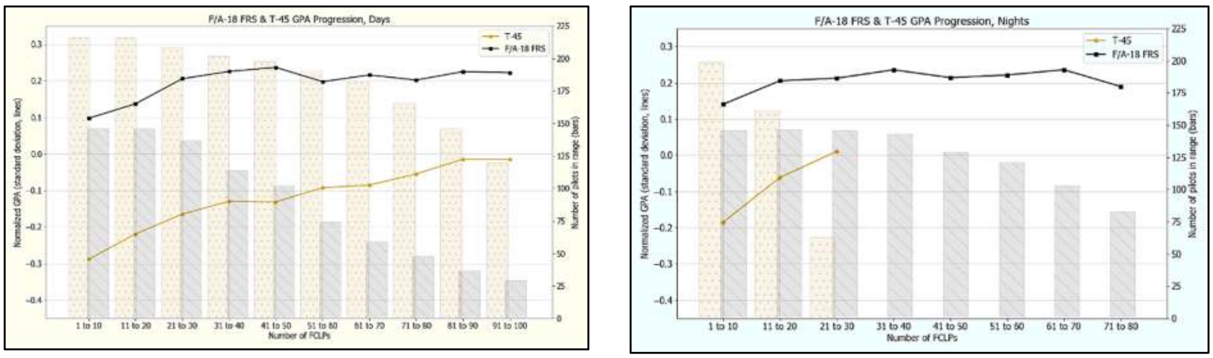

Figure 9. Normalized GPA vs number of FCLPs for days (left) and nights (right), T-45 and F/A-18 (FRS)

There are very few T-45 FCLPs performed at night. Based on the data points available, there appears to be dramatic improvement during T-45 night FCLPs. F/A-18 FRS pilots complete nearly as many night FCLPs as days. BGI observed incremental improvements in night FCLP performance for this group.

Acceptable Pass Progression

While the normalized GPA results above suggest pilots improve as they accumulate FCLPs, GPA is secondary to safety in LSOs' minds. Their main concerns are safety and predictability; the goal of undergraduate training and FRS is to develop pilots that will predictably perform safe landings. Since the safety of a given approach is nuanced for grades on the cusp, BGI looked to LSOs for a binary definition of broadly and generally acceptable types of approaches: perfect, OK, fair, and bolter.

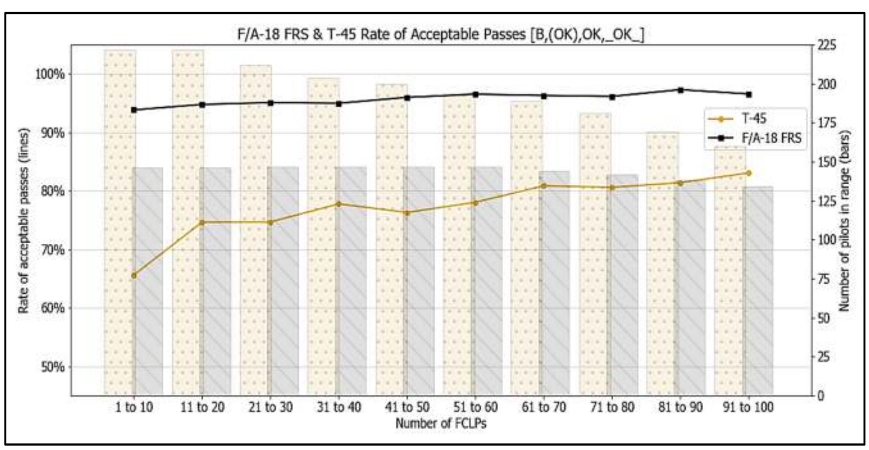

Figure 10. Rate of Acceptable Passes, T-45 and F/A-18 (FRS)

While behavior within a bolter or fair pass may be safe or risky, depending on the situation, grades below this threshold are unsafe by definition: no-grade bolter, no-grade, and cut pass. BGI now examined the number of acceptable passes these students perform as they accumulate FCLP repetitions (Figure 10). This provides a criterion-referenced metric for skill acquisition.

In Figure 11, BGI plotted the skill acquisition of T-45 pilots during FCLPs versus that of F/A-18 Fleet Replacement Squadron (FRS) pilots during FCLPs. A key observation is that pilots gain skill rapidly during their T-45 training, but exhibit flatter performance improvements during F/A-18 training (completed in FRS). Recalling that BGI saw similar growth for all groups in Figure 9, this suggests that F/A-18 FRS pilots are refining carrier-landing skills during FCLP and that T-45 pilots are acquiring carrier-landing skills during FCLP.

In Figure 12, it can be seen that pilot performance during the initial passes of CQ start below their ending FCLP performance. However, pilot improvement in this stage is more gradual than during FLCPs, particularly for T-45 pilots.

Similar to normalized GPA results, inspection of T-45 days (Figure 13) differs little from overall performance improvements due to data composition (few night FCLPs completed during T-45 training), with the divergence occurring about 10 passes sooner for this metric. Again, steep improvement can be seen during T-45 night FCLPs and relatively high, flat performance from F/A-18 FRS students.

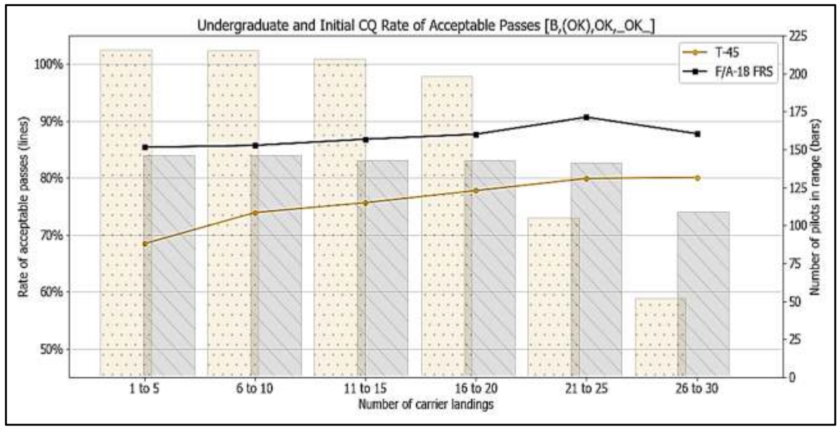

Figure 11. Rate of Acceptable Passes, early Undergraduate & Initial CQ

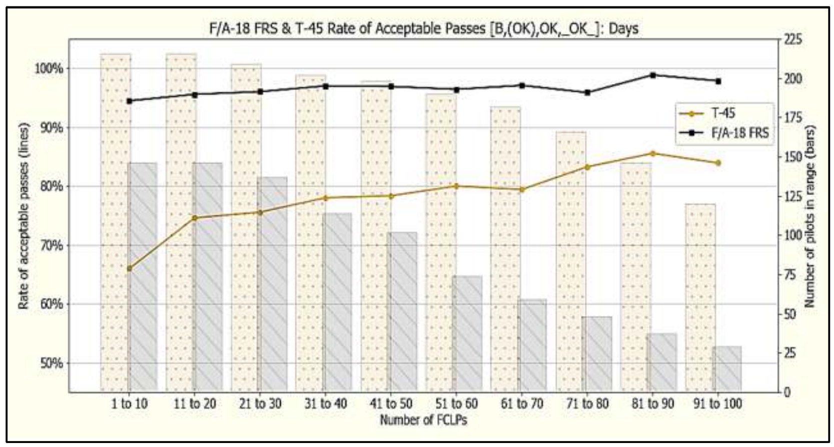

Figure 12. Rate of Acceptable Passes (days), T-45 and F/A-18 (FRS)

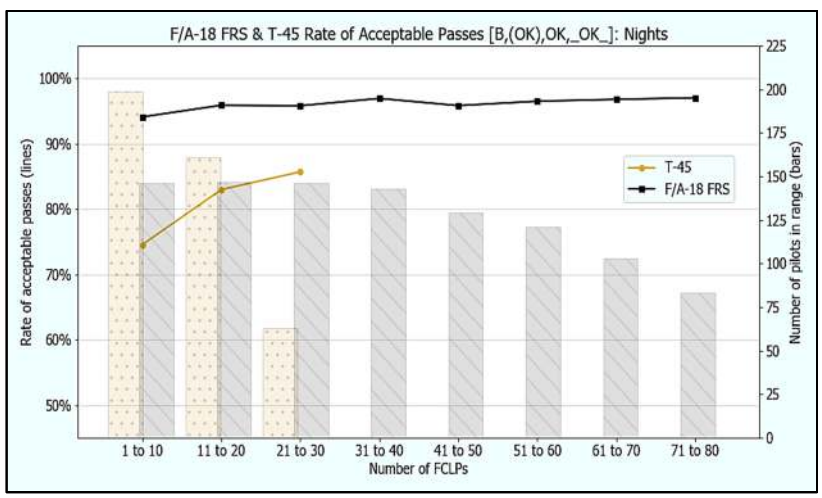

Figure 13. Rate of Acceptable Passes (nights), T-45 and F/A-18 (FRS)

Skill Acquisition

Because E-2 aircraft types will not be receiving PLM, the LSO community is interested in possible differences in the training required for these pilots and those of F/A-18 aircraft. There was not sufficient E-2 type FRS squadron data to compare skill acquisition during training, but BGI was able to compare ongoing skill acquisition as pilots progressed through their career. In Figure 11, the average scores of F/A-18 type, E-2 type, EA-6B pilots were plotted against the number of passes they have executed since transitioning from FRS to fleet squadrons.

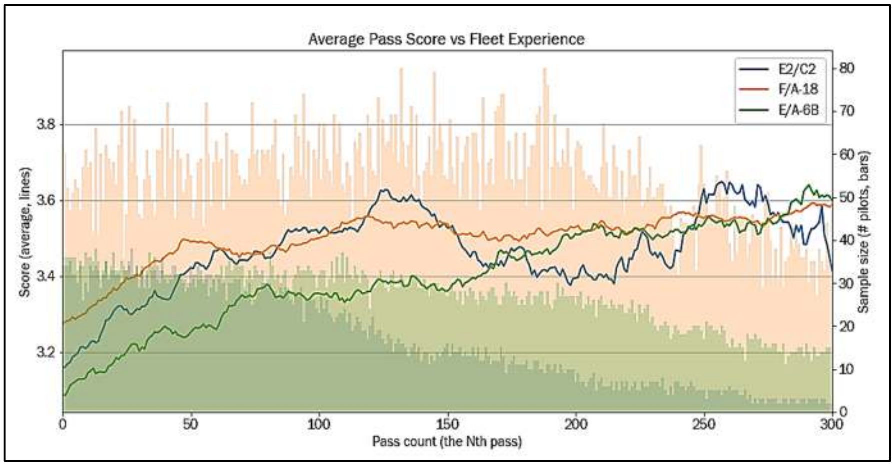

Figure 14. Skill acquisition vs experience (number of landings)

BGI observed that the learning rates for E-2/C-2 types and F/A-18 types follow a similar pattern. Pilots of these two aircraft types gain skill quickly during the first 50 career passes in their respective platforms. After this, pilots continue to improve at a slower rate as they gain experience.

It is important to note these experience rates are based on the number of landings, not on time. F/A-18 type pilots gain experience in roughly half the time of E-2 type pilots, since only one of the two pilots on each E-2 type flight gains carrier landing experience.

Skill Decay

Figure 15 shows skill decay as a function of how many days they have from carrier landing practice, including embarked landings and FCLPs. Each curve indicates the fleet average of scores on a pilot's 1st, 5th, and 10th landing after N days since a previous landing attempt. In this view, it can be seen that the majority of skill decay in F/A-18 models occurs in the 10-50 day range. Also notable is the trend line for the tenth landing after N days approximates the operational baseline for pilots returning to carrier landing practice after 20 or fewer days away. The trend line for the fifth and tenth landings appears to close roughly one- and two-thirds of the distance to the operating baseline, respectively. BGI found no trend line value that approximated the operational baseline for any range of time away longer than 20 days.

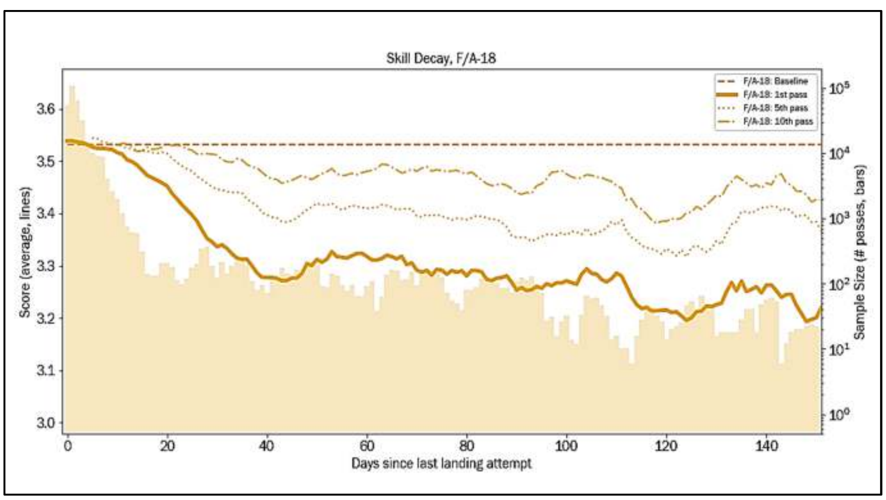

Figure 15. Skill decay vs time away from landing practice Comment Analyses

Comment Analyses

The ability to mine the wealth of LSO comment data available in APARTS has the potential to unlock hidden trends. The ability to cluster different "types" of passes could be a helpful technique for helping to diagnose students who may have common errors. Some of this functionality has been built into the application developed for the LSO School, LSO-DAT (Data Analysis Toolkit). While the technique is useful for training, it is not directly related to the pilot skill acquisition analysis results documented in this paper.

DISCUSSION

Recall the problem statements:

- P.S.1) Was there measurable skill acquisition during FCLP training periods before the introduction of PLM?
- P.S.2) What risks are involved in reducing the number of FCLPs required or recommended for naval aviators at various career stages?
- P.S.3) Was there a significant difference in the skill acquisition of E-2 pilots and F/A-18 pilots before the introduction of PLM to the latter platform?
- P.S.4) What is the expected effect of PLM on carrier landing skill acquisition?
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- P.S.6) What is the expected effect of PLM on skill decay in naval aviators?
- P.S.7) Can advanced analysis of LSO comments proactively identify bad flight habits before a dangerous pass occurs?
- P.S.8) Will PLM landings mask behaviors that could lead to dangerous landings?

In light of these problem statements and the results presented above, BGI discussed the following possible conclusions.

Interpreting Correlation Analysis

FCLP performance is not a strong predictor of Undergraduate and Initial CQ performance. This suggests that the impacts of reducing FCLP requirements in future training syllabi are unpredictable. BGI was unable to make recommendations for FCLP reductions based on this unpredictability and sought alternative metrics from which to approach the question of FCLP valuation.

The absence of fleet FCLP data in APARTS means that BGI was unable to perform a similar correlation analysis on non-training pilot data. FCLPs performed for the purpose of carrier currency may or may not be valid predictors of carrier performance. Fleet FCLP completion is typically recorded in a separate database system that BGI was not able to access for this analysis. Future research teams may address impact predictions for reducing FCLP recommendations on experienced pilots if they are able to obtain a sufficient history of FCLP data for this career stage.

Interpreting Progressions

T-45 FCLPs, completed in preparation for Undergraduate CQ, are SNAs' first physical experience with the risks of carrier-scale landings. Skill acquisition during this stage of training appears to be clear and measurable. BGI also noted that SNAs show the highest rate of unsafe landing attempts overall, as one would expect of the least experienced group. FCLPs for this least experienced group may currently serve the interest of risk management, as unsafe landings attempts aboard aircraft carriers are more likely to lead to catastrophic incidents than unsafe landings during field-based exercises.

The value of FCLPs for F/A-18 FRS students preparing for Initial CQ is less clear, leaving room to discuss gradual reductions under close monitoring of rates and frequencies of unsafe approaches. As noted above, BGI was unable to predict the impact that F/A-18 FRS FCLP reductions may have on Initial CQ based on correlation analysis results.
While experienced pilots returning from shore-based duties may or may not need a land-based refresher in order to regain the high-speed muscle memory required for reduced risk during their initial return to carrier-based duties, there was not sufficient fleet FCLP data in APARTS for such an analysis.

A major concern underlying LSO perspectives during discussions of making changes to FCLP recommendation tables is the unique risk of ramp strikes during carrier landings. While BGI's focus was on analysis of archival FCLP and carrier landing data, BGI was grateful to have little to no hard evidence of the real risks underlying this difficult task. Surely, much credit for this goes to the LSO community and their devotion to their mission. Absent guiding evidence and faced with high risk, one would be wise to monitor conditions closely and apply changes conservatively, as we are unable to quantifiably predict the impact of reductions at any of the career stages discussed above.

Interpreting Skill Acquisition

The results shown in Figure 11 suggest that, in the absence of PLM, E-2 and F/A-18 pilots tend to gain landing competence in two main stages, with significant growth in the first 50 career passes and more gradual skill refinements beyond this point. BGI was unable to predict expected effects of PLM on skill acquisition, as no sufficient comparison group exists in 2004-2015 subset. There did not appear to be significant differences in pre-PLM skill acquisition rates based on passes accumulated, noting that E-2 pilots accumulate landing experience at half the rate of F/A-18 pilots.

Results involving E-2 type landing data are difficult to interpret due to sample size discrepancies. No smooth or clear patterns are apparent in Figure 12. While skill acquisition over time appears to share periodic similarities across platforms, E-2 data availability for a given 10-day time bin was 100 records, compared to over 2,000 F/A-18 records per 10-day bin. Across the board, the E-2 data BGI obtained amounted to roughly 95% fewer records than available F/A-18 data. Better capture of FCLP records may help prevent disproportionate representation in future analyses.

Interpreting Skill Decay

Results suggest the majority of skill decay in F/A-18 models occurs in the 10-50 day range (Figure 15). In addition to this, pilots demonstrated operational baseline skill levels within 10 passes when return to activity occurred 20 or fewer days since last landing attempt. The LSO community may be able to use these results to inform future decisions on currency requirements.

The trend line for the fifth and tenth landings suggest that pilots are indeed regaining decayed skill upon return to carrier-type landings. BGI found no trend line that approximated the operational baseline for any range of time away longer than 20 days, but believes this is likely due to data quality discrepancies having an outsized impact on fleet records.

BGI was unable to predict the expected effect of PLM on skill decay, as no sufficient comparison group exists in 2004-2015 subset.

CONCLUSIONS

Analyzing the data, a conclusion may be drawn that simulator sessions and FCLPs provide some of the best opportunities for LSOs to assess student pilot performance on these metrics and correct dangerous landing behaviors prior to high-risk carrier landings during Undergraduate CQ, demonstrating the value in such learning exercises at this stage and a degree of baseline skill acquisition. While some amount of FCLPs may be valuable during FRS, it appears there was significantly less overall growth during FCLPs at this stage, whether based on normalized GPA or the more safety-focused "acceptable pass rate" metric. Fleet squadron FCLP data resident in APARTS is significantly lacking and fewer correlations may be drawn towards performance for fully-qualified and experienced aviators in regards to FCLP efficacy.

In light of the data issues described above, it is highly recommended that additional research be conducted after a sufficient history in the SHiPARTS data management paradigm is established. Applying analysis methods presented in this paper on future versions of the LSO dataset may provide valuable updated insights. Efforts to reduce the administrative overhead of data entry would likely improve the quality of future datasets.

The analysis in this paper is largely based on archival database material but represents a statistically significant historical baseline for pilot performance in a highly niche skill set. The information in this research may prove to be invaluable given that APARTS is no longer supported by Navy architecture, and all information resident within that database may be lost due to lack of incorporation into SHiPARTS.

PLM has already reduced overall FCLP requirements and further reductions, particularly for student F/A-18 pilots, are imminent. Given the future of CQ will certainly involve fewer FCLPs due to PLM capability and quite possibly no baseline skill acquisition in a trainer aircraft, fewer data points will be available to the LSO to interpret pilot performance and trends prior to embarked operations. Experienced LSO's recognize that regardless of data and trend analysis, the human performance piece still creates a level of unpredictability in pilot performance in such a dynamic and highly demanding environment as the aircraft carrier. Given decreased exposure to live training evolutions, innovative solutions in data analysis will be needed to adequately mine pilot performance and identify latent skill deficiencies before they are manifested in a catastrophic embarked mishap.

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