To the Graduate Council:

I am submitting herewith a thesis written by Brian T. Schrum entitled "F/A-18A-D Hornet Current and Future Utilization of Mode I Automatic Carrier Landings." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

Robert B. Richards

_____

Major Professor

We have read this thesis and
recommend its acceptance:

Peter Solies

_____

Rodney Allison

_____

Acceptance for the Council:

Carolyn R. Hodges

_____

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student record)

F/A-18A-D HORNET CURRENT AND FUTURE UTILIZATION OF MODE I AUTOMATIC CARRIER LANDINGS

A Thesis

Presented for the

Master of Science Degree

The University of Tennessee, Knoxville

Brian T. Schrum
May 2007

DEDICATION

I would like to dedicate this thesis to my beautiful and loving wife Nancy, my wonderful son Jacob and my adorable little girl, Leah. You are the joys of my life.

ACKNOWLEDGEMENTS

I wish to thank first and foremost, the United States Naval Test Pilot School (USNTPS) for their excellent instruction and insight into the evolving world of military flight test procedures and operations. I am very thankful for the opportunity to learn from such a great group of professionals - staff and students alike.

Secondly, I would like to thank the University of Tennessee Space Institute for providing me the means with which to pursue a Master's Degree. I would like to specifically thank your friendly staff and administrative personnel who have made this venture possible. Mr. Richards, thank you for your help and guidance during the writing of this thesis. Special thanks to Debbie Syders, who tirelessly stands the post as the UTSI administrative professional at NAS Patuxent River, Md. Thanks for letting me take my UTSI tests "*a little past your quitting time.*"

Last and certainly not least, I would like to thank the officers, enlisted, and engineers with which I have worked alongside at VX-23. It has been a pleasure to serve with you.

ABSTRACT

The purpose for writing this thesis is to prove the automatic carrier landing system (ACLS) a valuable Operational Risk Management (ORM) tool for recovering F/A-18A-D aircraft aboard the modern aircraft carrier. ORM is itself a subset of human factors and worthy of exploration in the aviation systems field. In proving the value of the ACLS, the author presents the following objectives: 1) describe the major components of the F/A-18A-D and modern aircraft carrier ACLS, 2) describe the current Mode I approach procedures, and the Precision Approach Landing Systems (PALS) certification process, 3) promote an increase in automatic landings during night time and low ceiling/visibility environments through an analysis of ACLS strengths and weaknesses, and 4) advocate the continued use of fully automatic carrier landings amidst addressing deeply rooted fleet squadron paradigms and the advent of future technologies.

The information gathered for this thesis came primarily from the author's own direct flight and test experiences as well as documentation of standardized Navy flight and test publications. Detailed background information on the ACLS and future landing programs along with data from the Naval Safety Center and the VX-23 Carrier Suitability department were used as evidence to support the findings.

The author concludes that the Mode I ACLS capability is extremely vital to the safe and expeditious recovery of the F/A-18A-D Hornet aircraft onboard the modern aircraft carrier that the Mode I automatic carrier landing system as currently structured and utilized is a highly effective risk management tool for naval aviation. The routine testing and certification of the precision approach equipment, all-weather capability, redundant cockpit data and voice safety network, plus enhanced aircraft carrier mobility through the use of Mode I approaches are all strengths of the ACLS system.

To enhance the effectiveness of the ACLS for future carrier operations, the author recommends: 1) creating RAG and fleet squadron command climates that promote and support the use of Mode I approaches, 2) increasing ACLS training for aircrew and maintainers, and 3) establishing a new CV-1 approach that can capitalize on JPALS functionality in order to improve upon automatic landings.

TABLE OF CONTENTS

Page

CHAPTER I. INTRODUCTION 1
PURPOSE 1
THESIS STATEMENT 1
DISCLAIMER 3

CHAPTER II. THE AUTOMATIC CARRIER LANDING SYSTEM 4
MAJOR AIRCRAFT CARRIER ACLS COMPONENTS 4
THE MODERN AIRCRAFT CARRIER 4
AUTOMATIC CARRIER LANDING SYSTEM (ACLS) 5
INSTRUMENT CARRIER LANDING SYSTEM (ICLS)..... 7
FRESNEL LENS OPTICAL LANDING SYSTEM (FLOLS/IFLOLS) 8
CARRIER AIR TRAFFIC CONTROL CENTER (CATCC) 10
LANDING SIGNALS OFFICER (LSO) 11
MAJOR F/A-18A-D HORNET ACLS COMPONENTS 14
THE F/A-18A-D HORNET AIRCRAFT 14
COCKPIT DISPLAYS 15
Heads Up Display (HUD) 15
Digital Display Indicators (DDI) 15
Multi-Purpose Color Display (MPCD) 16
Up Front Control (UFC) 16
COCKPIT CONTROLS 17
Automatic Flight Control System (AFCS) 17
Automatic Throttle Control (ATC) 18
Tactical Air Navigation (TACAN) 19
Instrument Landing System (ILS) 19
Datalink and Radar Beacon 20

CHAPTER III. THE MODE I APPROACH AND THE PALS CERTIFICATION PROCEDURE 22
CASE RECOVERIES 22
GENERAL 22
THE CV-1 APPROACH AND MODE I PROCEDURES 23
THE PALS CERTIFICATION PROCESS 26

CHAPTER IV. CURRENT ACLS MODE I EFFECTIVENESS 31
GENERAL 31

CHAPTER V. THE FUTURE OF AUTOMATIC CARRIER LANDINGS ……..... 36
GENERAL ……..... 36
JPALS ……..... 38
N-UCAS ……..... 40

CHAPTER VI. CONCLUSIONS AND RECOMMENDATIONS …… 42
CONCLUSIONS …….. 42
RECOMMENDATIONS ……. 43

BIBLIOGRAPHY ……..... 46

APPENDIX A ……..... 49

VITA ……..... 55

LIST OF FIGURES

Figure Page

1. The Modern Aircraft Carrier: *USS George Washington* (CVN-73) Sailing Off the Coast of New York, NY Following the September 11, 2001 Terrorist Attacks.....6
2. Location of AN/SPN-41 Azimuth and Elevation Antennas and AN/SPN-46 Antennas on the Modern Aircraft Carrier.....8
3. IFLOLS Visual Landing Aids.....10
4. CATCC Personnel at Work Onboard the *USS Lincoln* 12
5. F/A-18C Hornet Approaching the *USS Kitty Hawk* 13
6. Abbreviated Night Currency Requirements for F/A-18 Aircrew 39
7. The Northrop Grumman X-47B and Boeing X-45A J-UCAS.....41
A-1. The F/A-18A-D Hornet 50
A-2. Front Seat F/A-18A-D Cockpit Displays 51
A-3. Approaching the Landing Area at Approximately ¾ nm 52
A-4. Approaching the Landing Area Just Prior to Command Freeze.....52
A-5. The PALS Pattern and Correlation Example.....53
A-6. The PALS PQR Rating Scale 54

LIST OF ABBREVIATIONS

AB	Afterburner
ACLS	Automatic Carrier Landing System
AFCS	Automatic Flight Control System
AOA	Angle of Attack
APCS	Approach Power Compensator System
BIT	Built In Test
CATCC	Carrier Air Traffic Control Center
CAVU	Ceiling and Visibility Unlimited
CAG	Commander of the Air Group
CVW	Carrier Air Wing
CV	Designation for Aircraft Carrier
CVN	Designation for Nuclear Powered Aircraft Carrier
DARPA	Defense Advanced Research Projects Agency
DDCS	Digital Data Communication Set
DDI	Digital Display Indicator
FCC	Flight Control Computer
FCLP	Field Carrier Landing Practice
FCS	Flight Control System
FLOLS	Fresnel Lens Optical Landing System
FRS	Fleet Replacement Squadron aka the RAG
GPS	Global Positioning System
HOTAS	Hands On Throttle and Stick
HUD	Heads Up Display
ILS	Instrument Landing System
ICLS	Instrument Carrier Landing System
IFLOLS	Improved Fresnel Lens Optical Landing System
ILM	Independent Landing Monitor
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
ISR	Intellegence/Surveillance/Reconnaisance
JPALS	Joint Precision Approach Landing System
KCAS	Knots Calibrated Airspeed
Knot	Nautical mile per hour
LCCS	Landing Control Central System
LSO	Landing Signals Officer also called “Paddles”
MAX	Maximum rated thrust (maximum w/ afterburner)
MFS	Manned Flight Simulator
MIL	Military rated thrust (max power w/o afterburner)
MPCD	Multi-Purpose Color Display
NAS	Naval Air Station
NATOPS	Naval Aviation Training and Operating Procedures Standardization

NAVAIR	Naval Aviation Systems Command
NAVAIRHQ	Naval Aviation Systems Command Headquarters
NAVAIRWARCENACDIV	Naval Air Warfare Center Aircraft Division
NAWCAD	Naval Aviation Warfare Center – Aircraft Division
ORM	Operational Risk Management
OPNAVINST	Operational Naval Instruction
PA	Powered Approach
PALS	Precision Approach Landing System
PMA	Program Management Authority
PQR	PALS Quality Rating
PriFly	Primary Flight Control (Tower on the CVN)
R-DG	Receiving-Decoding Group
RAG	Replacement Air Group aka FRS
RTB	Return To Base
SOP	Squadron Operating Procedure
SPN-41	Designation of the Carrier ICLS/ILM
SPN-42/46	Designation of the Carrier ACLS
SRGPS	Shipboard Relative GPS
TPS	Test Pilot School
UCAS	Unmanned Combat Aerial System
USNTPS	United States Naval Test Pilot School
VMC	Visual Metrological Conditions
WOD	Wind Over Deck

CHAPTER I. INTRODUCTION

PURPOSE

The purpose of writing this thesis is to complete the requirements set forth by the University of Tennessee Space Institute for conference of a Master of Science Degree in Aviation Systems. This thesis serves many functions. First, it describes to the reader the major Automatic Carrier Landing System components on the modern aircraft carrier and the F/A-18 Hornet aircraft. Second, it describes the current Mode I approach and enlightens the reader on the certification procedures for the precision approach landing systems. Third, this thesis attests that fully automatic carrier landings are an extremely valuable resource for fixed wing recovery operations, primarily in the night time and reduced ceiling and visibility environments. Finally, it provides an argument for continued use of these systems throughout the naval carrier force by addressing future implications and squadron policies.

THESIS STATEMENT

The fully automatic carrier approach is defined as a precision instrument approach in which the aircraft flight control computers continuously receive discrete commands from the aircraft carrier landing system that in turn actuate the aircraft flight controls in order to establish and maintain an on glideslope / on azimuth flight profile to touchdown. In naval aviation, this capability is know as the Mode I approach. The United States Navy currently has only one aircraft type that is capable of fully automatic carrier approaches using the ACLS. This aircraft is the F/A-18 Hornet. The naval carrier aviation enterprise is currently in the midst of a significant transformation. Five years from now, the carrier air wing will be primarily comprised of F/A-18 Hornets. F/A-18E-F Super Hornets have already replaced the multi-role F-14 Tomcats. The primary organic tanking and sea surface surveillance aircraft, the S-3 Viking, has left the naval service. The EA-6B Prowler is scheduled to retire by 2010, with their electronic attack role shifting to the new EA-18G Growler. By the year 2016 naval aviation will most

assuredly have an airwing comprised of F/A-18 Hornets and the new F-35 Joint Strike Fighter. The aircraft carrier, as a primary instrument of national military power, will be called upon time and again to go in harm's way in order to protect global and national interests. Just as combat tactics, techniques and procedures will undoubtedly be modified to meet new adversaries, administrative flight tasks such as launch and recovery of aircraft will need to become safer and more efficient. It is the current and future means to recover aircraft that is the focus of this paper and while this thesis will concentrate principally on the capabilities of the F/A-18A-D, the following discussion is relevant for all Hornet models and series.

The F/A-18 Hornet community has for many years had the capability to automatically land aircraft via a fully automatic approach. In fact, naval aviation has had this proven capability for nearly 50 years. On August 12th, 1957, LCDR Don Walker successfully landed his F3D *Skyknight* on the *USS Antietem* (CVA 36) off Pensacola, Florida. This signaled the first flight test of the Automatic Carrier Landing System, designed primarily to automatically land ACLS equipped aircraft aboard ship in all weather conditions. By August 20th, 1957, 50 fully automatic landings were completed on the *Antietem*. On July 24th, 1969, the first fully automatic carrier arrestment using the newly updated AN/SPN-42 ACLS was successfully completed by LT Dean Smith and LTJG James Sherlock of Fighter Squadron 103 with their F-4 Phantom aboard the *USS Saratoga* (CVA 60) (Chinfo website, 2006).

In the author's opinion, one of the greatest technological advances made in the recovery phase of flight is the ability of an aircraft to complete a fully automatic carrier landing. The author will show in this paper that the Mode I fully Automatic Carrier Landing System capability is extremely vital to the safe and expeditious recovery of the F/A-18A-D Hornet aircraft onboard the modern aircraft carrier and will continue to be a valuable asset in 21st century naval aviation.

DISCLAIMER

This thesis expresses the views of the author alone. It is merely academic in nature and shall not be construed as future policy for carrier fixed wing operations or an official United States Navy stance on doctrine or policy.

CHAPTER II. THE AUTOMATIC CARRIER LANDING SYSTEM

MAJOR AIRCRAFT CARRIER ACLS COMPONENTS

THE MODERN AIRCRAFT CARRIER

The United States Navy currently has 11 operational aircraft carriers, as listed in Table 1. Aircraft carriers with the CV designation are conventionally powered, while the CVN designations indicate nuclear powered vessels. All operational carriers are equipped to handle non-precision and precision approaches. Each aircraft carrier operates and maintains four arresting wires for recovering aircraft, except the *USS Ronald Reagan*, which uses three wires. The bulk of the U.S. carrier fleet is comprised of nuclear powered ships in the *Nimitz* class (CVN-68 through CVN-76). It is worth noting that there are some minor differences between each carrier within the *Nimitz* class and those carriers outside this class in regards to landing area dimensions and distances between arresting wires; however, these differences have very little effect on the ACLS or approach procedures. The following specifications are taken from the *USS Enterprise* and are generally representative of all modern aircraft carriers (USS Enterprise and Carrier Airwing One LSO Guide, 2003):

- Overall Length: 1099 ft
- Overall Width: 235 ft
- Angled Deck Length (Landing area): 754 ft
- Landing Area Width: 136 ft
- Distance from Ramp (furthest aft edge of the flightdeck) to the IFLOLS: 493 ft
- Deck Elevation: 62 ft
- Landing Area Angle (angle from ship centerline to centerline of the landing area): 10 deg.
- Distance from the Ramp to the #1 (furthest aft) wire: 173 ft
- Distance from the Ramp to the #4 (furthest forward) wire: 293 ft

Table 1. 2007 U.S. Aircraft Carrier Inventory

DESIGNATION	CARRIER NAME
CV-63	USS KITTY HAWK
CVN-65	USS ENTERPRISE
CVN-68	USS NIMITZ
CVN-69	USS EISENHOWER
CVN-70	USS CARL VINSON
CVN-71	USS THEODORE ROOSEVELT
CVN-72	USS ABRAHAM LINCOLN
CVN-73	USS GEORGE WASHINGTON
CVN-74	USS JOHN C. STENNIS
CVN-75	USS HARRY S. TRUMAN
CVN-76	USS RONALD REAGAN

- Distance between each successive wire: 40 ft
- Normal run-out of the arresting gear wire on a trap: 340 ft

For the purposes of this thesis, the ACLS procedures described within are germane to all U.S. Navy carriers. A photo of a Nimitz class carrier is shown in Figure 1.

AUTOMATIC CARRIER LANDING SYSTEM (ACLS)

The current carrier ACLS is designated the AN/SPN-46(V3). It consists of a precision tracking radar, a ship motion sensor, and a high-speed general purpose computer. Two radar antennas are located on the aft end of the carrier island structure 30 to 60 feet above the flight deck. Each antenna provides ACLS steering commands or coupling commands to one aircraft at a time. Therefore, a maximum of two aircraft may be given steering commands at any given moment. The AN/SPN-46 computers and associated components are located in an equipment room within the ship superstructure, in close proximity to the radar pedestals.



Figure 1. The Modern Aircraft Carrier: *USS George Washington* (CVN-73) Sailing Off the Coast of New York, NY Following the September 11, 2001 Terrorist Attacks (Photo Courtesy of the GW website)

The heart of the carrier ACLS Mode I is the landing control central system tracking and comparison radar or LCCS, which transmits X-band signals from the carrier to the aircraft via a conical scan radar antenna. This radar system tracks the inbound aircraft, and compares the aircraft position to the desired glide path (Integrated Publishing, 9-2). There are five shipboard subsystems within the LCCS:

1. Tracking pulse radar set (Ka-band). This radar set locks on to the aircraft when the aircraft enters the acquisition gate. The system then tracks the aircraft in range, azimuth, and elevation until touchdown or waveoff.
2. Stabilization group. This group translates the actual radar-derived position vector of the aircraft to a stabilized deck-coordinated system referenced to the touchdown point on the flight deck.
3. Digital computer. This is a general-purpose computer used to provide functions for radar data stabilization, data filtering, and computations required for control of the aircraft.

4. Data link monitor. This subsystem continuously checks data link transmissions for errors. If the messages do not check properly, the monitor will switch the system to a downgraded mode or will generate a waveoff signal.
5. The control console. This console, located in CATCC, monitors and controls the various functions of the landing system (Integrated Publishing 9-2,3).

The ACLS display information is also presented to the Landing Signal Officer on the LSO platform. The ACLS provides the receiving aircraft with the following capabilities:

1. Data link roll commands used to intercept and lock onto the landing approach.
2. Data link pitch commands used to establish the proper glidepath.
3. The autopilot provides warnings if the ACLS becomes uncoupled or degraded (Integrated Publishing, 9-1).

The system does not guarantee a perfect landing, but it does ensure that the pilot and aircraft have the best and safest possible approach and descent to the carrier deck and touchdown (Integrated Publishing, 9-1).

INSTRUMENT CARRIER LANDING SYSTEM (ICLS)

The carrier ILS is designated the AN/SPN-41. It consists of a pulse-coded scanning beam radar and separate azimuth and elevation transmitting units. The transmitting units consist of an antenna, transmitter, and stabilization systems. The azimuth transmitter (radome) is located on the fantail of the carrier, directly on the landing area centerline. The elevation antenna (radome) is located on the superstructure's starboard side aft. The ILS radar transmits the glide path pulse-coded Ku-band information from the carrier to the aircraft. Both elevation and azimuth signals are processed by the receiving-decoding group (R-DG) on the aircraft (Integrated Publishing, 9-1). When used as a primary carrier landing aid, the SPN-41 system is designated the ICLS. When used during ACLS approaches, as is the normal operating

procedure during the CV-1 approach, the SPN-41 acts as an Independent Landing Monitor (ILM). The Independent Landing Monitor function allows the pilot to reference ILS azimuth and elevation signals and compare them to ACLS azimuth and elevation indications in the cockpit. If there is a significant difference in ILS and ACLS indications, there may be a problem with one or more systems. Ideally, the ILS and ACLS information displayed to the pilot should match, thus imbuing the pilot with a high confidence in the landing aids. AN/SPN-41 and AN/SPN-46 antenna locations are provided in Figure 2.

FRESNEL LENS OPTICAL LANDING SYSTEM (FLOLS)

The FLOLS is an electro-optical pilot landing aid featuring two identical channels of stabilization complete with gyro/sensor units, electronic computers, monitoring circuits, built-in maintenance facilities and automatic trim stabilization units.

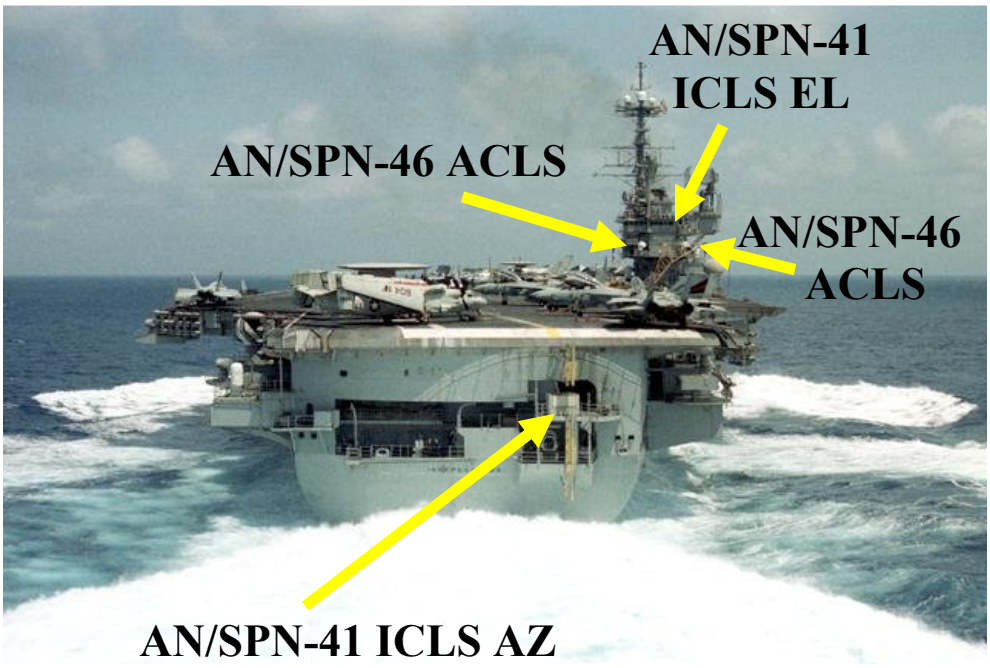


Figure 2. Location of AN/SPN-41 Azimuth and Elevation Antennas and AN/SPN-46 Antennas on the Modern Aircraft Carrier
(Photo Courtesy of VX-23 Archive)

Each vertical cell on the FLOLS emits a yellow beam of light or "meatball" that informs the pilot if he is above, below, or on glidepath when referenced to the horizontal green datam lights. The bottom light cell in the vertical column of lights is red. If the pilot sees this red light, he knows his aircraft is dangerously low and more power must be added to place his aircraft on or above the glideslope. The red lights on each side of the "meatball" are the waveoff lights. If the LSO or control tower notices an unsafe condition developing with the aircraft on final approach, the waveoff lights will illuminate, signaling the pilot to take the aircraft around for another landing attempt. Pilots who are able to stabilize their aircraft while maintaining optimal angle of attack, remaining on the centerline of the landing area, and keeping the vertical "meatball" lined up with the green datam lights throughout the approach are all but assured a very nice, smooth landing to the 3-wire.

There are two types of stabilization used for the FLOLS. Line stabilization stabilizes the FLOLS for pitch and roll motions of the ship, maintaining a predetermined line in space at the intersection of the FLOLS light plane and the true vertical plane through the centerline of the angled deck. This means that the stabilized glideslope translates vertically with the up and down movements of the ship. This is not ideal because pilots may have a tendency to chase the glideslope indications and may get out of phase with the motion of the flight deck just before landing. The primary mode of FLOLS stabilization is Inertial. Inertial mode is, in effect, line stabilization that also accounts for heave motion. This means that no matter what motion the ship is making, as long as the aircraft is stabilized on the proper glideslope, on the optimum AOA and on centerline, the aircraft will touchdown at the targeted point of landing. It is important to note that the ACLS system itself uses Inertial stabilization when an aircraft is greater than ½ nm from touchdown and line stabilization when less than ½ nm (for deck motion compensation effects). A pilot flying a Mode I approach should therefore see a center ball all the way to touchdown, regardless of ship motion. There is a potential danger in using inertial mode. If the carrier is experiencing rough seas and the landing area heave motion rate and/or magnitude is substantial, then the pilot may get dangerously close to the back or sail over the ramp area just prior to touchdown even though he is seeing a

center ball. There are stabilization limits for the FLOLS, and they are +/- 6 deg. in pitch and +/- 10 deg. in roll. The FLOLS automatically corrects the lens settings for static mistrim of the ship to maintain a constant hook touchdown point (LSO NATOPS, 4-2).

IFLOLS is the improved version of the FLOLS in that it doubles the amount of vertical "meatball" cells thus improving the fidelity and refinement of glideslope deviations seen by the pilot. IFLOLS stabilization limits are a bit smaller than the regular FLOLS, with maximum acceptable pitch at +/- 1.5 deg. and roll at +/-8.5 deg. The IFLOLS stabilizes up to a maximum ship heave of +/- 5 ft. IFLOLS is currently the apparatus used on all U.S. Navy aircraft carriers and the majority of naval air bases. While the IFLOLS is a very important part of normal carrier recovery operations, it is very useful as a cross check during the Mode I approach. An IFLOLS picture is shown in Figure 3.

CARRIER AIR TRAFFIC CONTROL CENTER (CATCC)

The CATCC is comprised of an air traffic controller, supervisor team and associated equipment. It is similar to a civilian land based approach/departure control. Among other responsibilities, CATCC coordinates the safe separation of aircraft during the recovery phase of flight during low ceiling/low visibility or night time carrier operations. CATCC controllers handle both marshall and approach responsibilities for

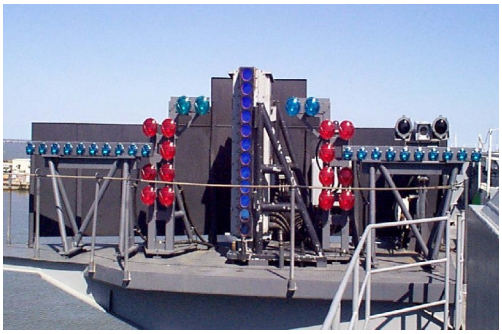


Figure 3. IFLOLS Visual Landing Aid.
(VX-23 Picture Archive)

the carrier. Aircraft awaiting recovery are marshaled behind the carrier and given approach instructions. Upon commencement of an approach, each aircraft is handed off to an approach controller who will monitor the aircraft to touchdown. CATCC communications with each aircrew can be heard in the control tower and on the LSO platform. Just as the ACLS system has two channels for control of aircraft, CATCC has two dedicated radio frequencies to more efficiently communicate with aircrew and sequence individual approaches. During Mode I approaches, CATCC personnel acquire, track and process radar and data link communications via the ACLS equipment to ensure proper automatic aircraft response to given commands. Mode II approaches occur given the conditions above, with one exception. The exception is that the Hornet flight controls do not automatically respond to given commands from the ship; the pilot must manually control the aircraft using the ACLS cues on the HUD and DDI. Approach procedures are discussed in the next chapter. An example of a CATCC control room is shown in Figure 4.

LANDING SIGNALS OFFICER (LSO)

While not specifically part of the carrier ACLS system, the LSO serves a very important function in the recovery of all fixed wing aircraft. The LSO is ultimately responsible for the safe and expeditious recovery of aircraft aboard the ship. The LSOs work as teams aboard the carrier. Each team is usually comprised of five junior squadron pilots and headed by a senior ranking carrier airwing LSO. Team members typically are from different squadrons and thus operate different aircraft. They are the squadron carrier landing environment subject matter experts for their individual platforms. When recovering aircraft, the LSOs congregate on the LSO platform. The LSO platform is located on the port side of the ship just outboard of the landing area and slightly aft of the 4-wire. Each team member has a function, whether it is controlling or back-up LSO, deck safety observer or scribe.

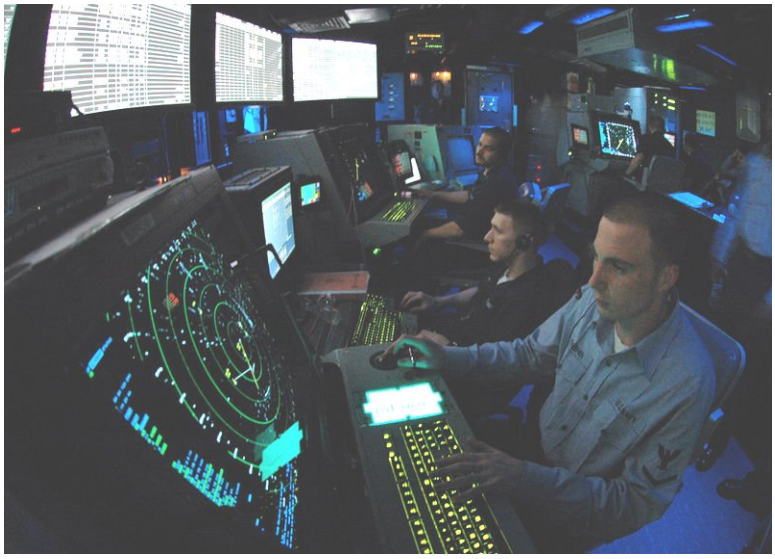


Figure 4. CATCC Personnel at Work Onboard the *USS Lincoln*
(Photo Courtesy of the *USS Lincoln* website)

Controlling and back-up LSOs are responsible for observing the aircraft glideslope and line-up on final approach, assuring each aircraft is in the correct landing configuration, confirming that the arresting gear and IFLOLS settings are correct for the type aircraft on final, and verifying that the aircraft can make an unobstructed landing. The scribe translates the landing comments and grade given by the controlling LSO to each pilot on every landing attempt into an LSO log book. After the recovery is complete, the LSOs secure the platform and debrief each aircrew on the pass or passes they flew during that evolution.

In the event that an unsafe situation develops, the LSOs may inform the pilot to waveoff the approach with voice communications or through the use of the pickle switch. The pickle switch is a trigger type device that has two buttons. One button is used to engage the waveoff lights on the FLOLS to visually tell the pilot to take the aircraft around the pattern for another landing attempt, while the other button operates the "cut" lights. The "cut" lights were used by LSOs in WWII to signal to the pilots to cut their engines upon safely touching down in the landing area. This would help stop the forward momentum of the aircraft and minimize the strain on the crude arresting gear of the time. In modern times, the "cut" lights are used to signal to the pilot to *add* some power to his

aircraft, as the LSO perceives a potentially dangerous situation developing. The pilot should increase power as the LSO requests. Use of the "cut" lights helps to declutter the tower voice communications by giving a visual command to the pilot, allowing the pilot to better focus on the pass.

The LSOs are the last line of defense for approaching aircraft before they touch down. The LSOs have the ability to talk to each pilot via a headset as they enter the final phase of the approach, helping each pilot adjust the aircraft flightpath to assume a more stable profile. It is an acquired and perishable skill that requires quick thinking and logical judgment, sometimes in very high stress circumstances. Due to their calm demeanor and knowledge of the aircraft and ship recovery characteristics, they are a very valuable resource. Figure 5 below is a view of an approaching F/A-18C Hornet from the LSO Platform. Having described the major aircraft carrier ACLS components, the following paragraphs describe the major F/A-18 Hornet ACLS components.



Figure 5. F/A-18C Hornet Approaching the *USS Kitty Hawk*
(Photo Courtesy of LCDR Chris Hurst, CVW-5 Paddles)

MAJOR F/A-18A-D HORNET ACLS COMPONENTS

THE F/A-18A-D HORNET AIRCRAFT

The F/A-18A-D Hornet is a fighter/attack aircraft built by McDonnell Douglas Aerospace. The F/A-18A/C variants are the single-seat cockpits, while the F/A-18B/D variants are two-seat. The aircraft is powered by two General Electric F404-GE-400 (-402) turbofan engines with afterburner. The aircraft is equipped with a multi-mode radar and gun in the nose section, with nine weapon stations available for various air-to-air, air-to-ground and external fuel tank configurations. Unique airframe characteristics include twin vertical stabilizers angled outboard from the vertical as well as leading edge extensions (LEX) on each side of the fuselage from the wing roots to just forward of the windshield. The flight control system is electronic "fly by wire" with a backup horizontal stabilator mechanical mode. The flight controls are hydraulically actuated and consist of ailerons, horizontal stabilators, twin rudders, leading edge flaps and trailing edge flaps. Two flight control computers are designed to provide the pilot with excellent handling characteristics in all flight regimes, including the landing phase of flight. In the landing configuration, the datalink, autopilot, enhanced flight control system and auto throttle functionality offer a completely automatic "hands free" landing capability of the aircraft. The rugged landing gear, launch bar and tail hook as well as a simplified, coded maintenance trouble shooting system are excellent characteristics that suit the Hornet well for high tempo combat carrier deployments. Pilot interface with this aircraft is accomplished through various displays and cockpit controls.

The F/A-18 Hornet is used by the United States Navy aboard aircraft carriers as the all purpose, multi-role asset of the embarked airwing. Typically four Hornet squadrons will deploy aboard a carrier for operations, with each squadron maintaining 10 to 12 aircraft. Currently the F/A-18 Hornet and F/A-18E/F Super Hornet are the only fixed wing aircraft certified to conduct fully automatic carrier arrestments. This is due to the high fidelity automatic flight control, automatic throttle, datalink and beacon systems inherent to the Hornet. Figure A-1 details the basic F/A-18A-D aircraft.

COCKPIT DISPLAYS

Displaying relevant, comprehendible and timely information to the Hornet pilot is completed through the Heads Up Display (HUD), two Digital Display Indicators (DDI), and a Multi-Purpose Color Display (MPCD). These displays, along with the Up Front Control (UFC) allow the pilot to interface with the ACLS and ICLS/ILM during recovery. Figure A-2 is a picture from the pilot seat showing the HUD, two DDIs and the UFC just prior to takeoff roll.

Heads Up Display (HUD)

The HUD is located on the top of the center main instrument panel and is the primary flight attitude instrument for the pilot. The HUD is approximately 8" x 6" in height and width respectively. The HUD receives Air-to-Air, Air-to-Ground, navigation and steering control information from the aircraft mission computers, displayed on a combining glass assembly. HUD displayed airspeed is in KCAS. During an ACLS approach, the pilot receives datalink, TACAN, ACLS, and ILS information on the right side of the HUD. The HUD is electronically interfaced with the Up Front Control (UFC).

Digital Display Indicators (DDI)

The two DDIs (left and right, or LDDI/RDDI) are located on the main instrument panel to the left and right of the UFC. The DDIs are used by the pilot to bring up certain unique sets of information, such as weapon stores data, FLIR video, flight control status, engine parameter data, and radar attack displays via the mission computers. Each DDI display window is 5"x 5" with twenty pushbuttons surrounding each DDI. When approaching the ship for an automatic landing, the situational awareness, or SA, page alerts the pilot to datalink discrete messages and events that are vital to the aircraft and carrier landing system status. The RDDI display is pilot selectable during an approach and the attitude indicator or flight control page is normally selected for quick reference.

Each pushbutton, when labeled on the DDI menu screen, allows the pilot to access more information (sub-levels) or perform certain actions.

Multi-Purpose Color Display (MPCD)

The MPCD is located in the center lower console of the main instrument panel and is used primarily to display a colored moving map with an overlay of navigation symbology. The MPCD moving map provides a top down view of aircraft location with respect to other waypoints, TACAN stations, carrier location, and airspace boundaries. The MPCD screen dimension is 5"x 5", with 20 pushbuttons surrounding the display. The MPCD allows the pilot to run a courseline through the carrier's TACAN location via a course toggle switch next to the MPCD, to help orient the pilot to the ship's expected final bearing (EFB), or base recovery course (BRC), useful in shipboard recovery operations. This display greatly enhances the pilot's overall understanding of where the aircraft is positioned relative to other aircraft and marshal airspace for recovery. It further aids the pilot during completion of the standard CV-1 approach to the ship. The ACLS is activated when the ACL button is depressed on the MPCD. ILS symbology is activated when the ILS button is depressed. Provided the ILS, ACLS and TACAN power is applied via the UFC, symbology will be seen on both the MPCD and the HUD.

Up Front Control (UFC)

The Up Front Control is located on the main instrument panel just below the HUD. The UFC enables the pilot to enter navigation, radio and weapon information through use of a numeric keypad. Radio frequencies may be entered manually or up to 20 preset frequencies may be programmed and selected in two distinct radios. Each radio has a volume control knob located on the UFC. There are six function selector pushbuttons on the bottom of the UFC for ON/OFF control of the autopilot (A/P), Identification Friend/Foe (IFF), TACAN, ILS, datalink (D/L), and aircraft beacon (BCN). Depressing one of these function selector pushbuttons illuminates the option display

window and scratchpad for pilot selectable data entry. The scratchpad and option display windows allow for quick and accurate access of information. A colon next to an option in the option display window means the pilot has selected that functionality via the option select pushbutton.

COCKPIT CONTROLS

Automatic Flight Control System (AFCS)

The F/A-18A-D Hornet flight control system, when working under normal circumstances (without any problems), operates under what is called a Control Augmentation System (CAS). The CAS or "fly-by-wire" uses pilot control stick inputs along with various air data/environmental characteristics that in turn feed into the hub of the flight control system, the Flight Control Computers (FCCs). The two FCCs process the pilot and environmental inputs to formulate discrete signals to send to control surface actuators that translate into stabilator, aileron, flap, and rudder movement. Flight control movement is in turn driven by two hydraulic systems that are powered by the engines. The control stick has a longitudinal and lateral pitch trim switch that can be actuated by the pilot to zero out pitch and roll rates, and is designed to ease pilot workload during long transits or when conducting a manual landing approach. Autopilot mode, and therefore a Mode I approach, is disengaged through pilot activation of a paddle switch located at the base of the control stick.

A conventional flight control system is directly manipulated by control stick displacement forward and aft that allows for longitudinal aircraft control provided by the stabilators while left and right stick movement allows for lateral control via ailerons. Rudder normally supplies aircraft directional control. This is not necessarily always the case with the Hornet however; as different flight regimes, such as very high or low airspeed maneuvering, call for flight control signals from the FCCs to provide sometimes unconventional control surface displacements, resulting in desired aircraft response. For example, the FCCs may not only respond with added stabilator and aileron displacement,

but also differential leading and trailing edge flaps or rudders. This unique flight control design incorporates added maneuverability to the Hornet. When in the landing approach configuration, the Hornet leading and trailing edge flaps are generally in fixed down positions, while the stabilators, ailerons and rudders are designed to give optimal lateral, directional and pitch control for the pilot.

When conducting an ACLS approach, the pilot relies on the Hornet automatic flight control system, digital data communication set (DDCS) and the onboard receiving-decoding group (R-DG) to operate in harmony with the carrier generated command signals. The AFCS provides the switching and signal conditioning, engage logic, command signal limiting and failsafe interlocks to couple and process discrete datalink signals to the pitch and bank channels of the flight controls (Integrated Publishing, 9-1). Automatic synchronization is provided in pitch, roll and yaw. The DDCS receives the aircraft carrier datalink messages and then sends the signals to the AFCS for desired aircraft response. The R-DG determines the glidepath errors sent from the aircraft carrier landing system radar and converts the data into signals that are displayed on the cockpit HUD for the pilot to either monitor the Mode I automatic approach or manually make azimuth and glideslope corrections to control the aircraft (this is known as a Mode II approach). The Hornet autopilot mode is the interface used to engage the automatic flight control system for ACLS approaches and is enabled when the A/P function selector is pushed on the UFC. The display consists of attitude hold, heading select hold, barometric and radar altimeter hold, and coupled steering. During automatic approaches to the carrier, pilots need to engage the CPL option.

Automatic Throttle Control (ATC)

The automatic throttle control, when used in the approach mode, automatically maintains an optimum approach angle of attack by modulating engine thrust via the Flight Control Computers (FCCs). The computers use angle of attack and various other aircraft and environmental inputs to generate thrust commands to the engines. Approach landing mode is entered by pressing the ATC button with the flap switch in HALF or

FULL and with the trailing edge flaps extended. When flying coupled Mode I approaches, the use of the auto throttle system significantly enhances the reliability of the Mode I by reducing pilot-induced angle of attack and glideslope errors through thrust manipulation, resulting in a more stabilized approach and improved hook touchdown point accuracy. In fact, engagement of the ATC system is a requirement when conducting a fully automatic carrier approach. When flying manual (not Mode I) approaches to the carrier, ATC may be engaged during the approach to help pilots maintain glideslope and optimum angle of attack. This is not considered a fully automatic approach, as it requires pilot initiated forward/aft control stick movement to modulate thrust. This fore and aft movement of the stick can become very rapid during the final part of a carrier approach as it translates into very quick bursts or pauses in thrust to maintain glideslope and AOA.

Tactical Air Navigation (TACAN)

The F/A-18 TACAN system relays precise relative bearing and range to a TACAN ground or ship station. The TACAN system operates by line of sight, with a general operating range near 200 nm. TACAN power and channel switching is accomplished through the UFC. During an approach to the ship, TACAN distance is the primary means by which the pilot can determine accurate range to the carrier. TACAN range and bearing information is available to the pilot on the MPCD and the HUD.

Instrument Landing System (ILS)

The F/A-18 ILS is an all weather guidance system that decodes transmitted azimuth and elevation signals during a carrier approach. The aircraft ILS is composed of two subsystems, the receiver and decoder. The ILS receiver receives coded transmissions of azimuth and elevation guidance from the aircraft carrier transmitters. The receiver then transforms these signals into coded pulses, able to be processed by a decoder. The decoder simply takes the coded pulses and converts them to azimuth and elevation

command signals via the R-DG for display on the HUD – referenced to the HUD velocity vector. Pilot corrections to the ILS system in the Hornet are very similar to the civilian counterpart.

Datalink and Radar Beacon

The datalink control system, located in the instrument bays below the cockpit, provides the means by which control signals are sent from the carrier to an ACLS capable aircraft for guidance. Distinct datalink signals received by the F/A-18 on final approach come in two forms from the ship. One signal path is used to inform the pilot of ACLS status throughout the approach by displaying datalink information on the HUD or SA page on the DDI. The second signal path is used to send longitudinal and lateral commands during an automatic approach through inputs to the FCCs via the DDCS that in turn actuate the flight control surfaces. In addition to these two signal message paths, there are two Universal Test Messages (UTMs) that are periodically sent from the ship to all ACLS capable aircraft. The UTMs have a unique and constant message. The aircraft datalink equipment is commanded to accept these UTMs in order to determine aircraft ACLS capability. Two criteria must be met for the pilot to receive the proper ACLS control information and commands from the aircraft carrier. Each F/A-18 must have the correct ship datalink frequency set in the UFC and the CATCC controller must select the correct individual aircraft datalink address.

The F/A-18 radar beacon is located on the bottom of the aircraft near the nose cone just in front of the nose landing gear. The purpose of the radar beacon is to receive the Ka-band signal interrogations from the aircraft carrier's Landing Control Center System (LCCS). The beacon then transmits X-band replies to the carrier to provide precise aircraft position data. The F/A-18's skin track can be picked up by the ship's radar system; however, the radar beacon on the aircraft provides for a contained point source necessary to achieve the accuracy needed to correctly place the aircraft within a very narrow 3-D window to affect a safe carrier arrestment. Having described the major

aircraft carrier and F/A-18 Hornet ACLS components, the author will now describe the Mode I approach and certification procedures.

CHAPTER III. THE MODE I APPROACH AND THE PALS CERTIFICATION PROCEDURE

CASE RECOVERIES

GENERAL

The type of recovery used is highly dependant on the environmental conditions the ship is experiencing at the time of recovery. Types of recovery are broken into three distinct Cases. Case I recoveries are utilized when the weather is nice, more specifically when the cloud ceiling is greater than 3000 feet and visibility is greater than 5 nm around the carrier control zone (typically a 5 nm radius around the ship). In this instance, recovery aircraft orbit over the carrier at various assigned altitudes based on airwing standard operating procedures. The aircraft or flight at the lowest altitude, when the flightdeck is ready for recovery, descends for a VFR overhead approach. Once this altitude is vacated, the next highest aircraft or flight would descend to fill the altitude gap left by the previous aircraft. This "collapsing" of the aircraft stack overhead the ship continues until all aircraft have successfully arrested aboard the ship. Case II recoveries are utilized when the cloud ceiling is greater than 1000 feet and less than 3000 feet and the visibility is greater than 5 nm. These recoveries require the pilot to marshal behind the ship, fly the CV-1 approach (described below) and then once below the ceiling, commence a VFR overhead approach as stated above in Case I weather conditions. Case III recoveries are utilized when the weather conditions are less than 1000 ft ceiling or visibility is less than 5 nm, and during all night time operations. Currently, the overwhelming majority of Mode I ACLS approaches are made under these conditions. The specific Case recovery determination is made by the Air Boss in the control tower; however, airborne aircrew can recommend a move to a different Case recovery if the weather does not materialize as forecast. The Mode I approach is accomplished via a standard, published profile until radar lock-on by the CATCC approach controller occurs at approximately 6 to10 nm behind the aircraft carrier. The following paragraphs will describe the CV-1 and Mode 1 approach procedures.

THE CV-1 APPROACH AND MODE I PROCEDURES

The CV-1 instrument approach procedure is utilized in carrier aviation much the same way a Standard Terminal Arrival Route is in the civilian world. The CATCC controllers are heavily tasked during recoveries, so a standardized approach profile paves the way for more predictable traffic flow. Predictable traffic flow leads to reduced stress on controllers and a better ability for the controller to adapt to changing conditions. The goal of the CV-1 is to efficiently sequence marshaling aircraft out of altitude and onto final approach course in a predictable manner, culminating in one aircraft crossing the flightdeck ramp every minute (or so) until recovery is complete. This requires both science and art. CATCC controllers need to proactively and successfully direct aircraft, while aircrew need to leave the assigned marshal fix at the prescribed time and fly the CV-1 profile as published. Only with the CATCC controllers and pilots working together as a team, can the airwing execute recovery as desired.

Pilots begin a Case III recovery and consequently a Mode I approach, by contacting marshal frequency for holding instructions. Holding priorities are established by CATCC based on factors such as fuel remaining, and aircraft are generally positioned between 20 and 35 nm behind the ship – stacked with adequate vertical separation. Holding instructions include:

- Case recovery being used
- Type of approach (almost always the CV-1)
- Final bearing (extended heading of the landing area centerline)
- Weather and deck conditions
- Divert field data
- Time hack
- Where to hold (radial, distance, and altitude) aka your IAF
- Expected approach time for your aircraft (when you are to leave IAF)

Pilots then conserve fuel in holding by flying maximum endurance airspeed until their approach time arrives. It is also in marshal where pilots request the Mode I approach with CATCC. Each F/A-18 pilot makes final preparations for the approach,

including initializing the aircraft ACLS system. This initialization turns on the datalink, radar beacon and ILS systems and runs an initial BIT. Next, the pilot reports leaving marshal on time (at the IAF) and is given the updated altimeter setting by the marshal controller. The pilot begins executing the CV-1 profile displayed in Figure A-5.

As the aircraft descends out of the IAF, maintaining the prescribed airspeed, the pilot sets the TACAN courseline through the aircraft carrier's TACAN station in the direction of the ship's final bearing as stated in the marshal instructions. This will help in initially positioning the aircraft directly behind the ship. It is here that the pilot may receive the first indications of the ILS needles on his HUD and will be told by approach control to fly his ILS needles until ACL lock-on occurs. The pilot is requested to switch to approach control and will remain on that frequency until safe on deck. "Platform" is reported by the pilot when passing 5,000 ft AGL. This is an indication to the approach controller that the pilot is decreasing his rate of descent in order to safely achieve straight and level flight at 1,200 ft AGL by 10 nm. Once established level at 10 nm, the pilot configures his aircraft for landing. This entails lowering the landing gear and flaps to full down, as Hornet Mode I approaches can only be flown in full flaps. After the configuration change is complete, the pilot engages the ATC. At approximately 6-8 nm behind the ship, the aircraft enters the AN/SPN-46 acquisition window. With a positive indication that the SPN-46 acquisition has occurred, the carrier begins linking vertical and lateral error signals to the aircraft. These error signals represent the actual displacement of the aircraft from the desired approach path (Integrated Publishing, 9-5). The ACL RDY indication is a prerequisite for coupling the flight controls to the ship commands. A "tadpole" steering cue ( ) on the HUD visually represents where the pilot needs to position the aircraft to achieve proper glideslope and azimuth in the approach. Approach control will verbally notify the pilot that successful acquisition has occurred, but confirmation is needed before guidance commands are sent. The pilot responds to the controller with the direction (elevation and azimuth) that is needed to fly to intercept the "tadpole". Once the controller concurs that the pilot is observing the correct CATCC ACL signals, the controller calls for the pilot to "report coupled". At this point, the ILS needles and ACL tadpole indications should be superimposed. The ILS

takes on the ILM responsibility by comparing/contrasting the two approach signals to see if they adequately match. Correlation of these signals will be discussed in the PALS certification chapter of this paper.

The pilot should now have the aircraft in level flight at 1,200 ft AGL, in the landing configuration with ATC selected and the landing checklist complete. At this point, the pilot will be anywhere between 4-6 nm from the ship and ready to couple to the ship commands. To couple the aircraft to the ship commands requires the pilot to select the CPL pushbutton on the UFC. With the datalink connection established and the aircraft receiving valid pitch and roll commands from the carrier, the approach controller will now verbally notify the pilot that they are "sending commands". At this point, the pilot is not actively flying the aircraft. He will report back to the controller "command and control." Pitch and roll commands sent from the ship are now guiding the aircraft to seek an on-glideslope and on-azimuth profile.

It should be noted that most couple attempts occur between 4 to 6 nm behind the aircraft carrier. While the above process may seem laborious at first, it actually takes very little time. Proficient aircrew and CATCC controllers can couple an aircraft and send commands in a matter of seconds. On the CV-1 approach, tipover occurs at 3 nm and 1,200 ft AGL. Tipover is the location on the approach profile where the aircraft intercepts the glideslope. At approximately 10 seconds prior to touchdown, deck motion compensation is added to aircraft commands. Compensation is in the form of a *slight* increase or decrease in aircraft attitude as needed to adjust for the movement of the touchdown point in response to the carrier's movement (Integrated Publishing, 9-5). At approximately 2 seconds prior to touchdown, the pitch and roll commands sent to the aircraft are frozen, allowing the aircraft autopilot to hold the last commanded attitude until touchdown. Figures A-3 and A-4 show sequential cockpit views of the carrier approach.

When touchdown occurs, the throttles are brought to full military power in the event of a bolter or hook skip. The autopilot and auto throttles disengage on touchdown. If the tailhook grabs a wire, then a successful arrestment has taken place and the aircraft will taxi out of the wires for parking – clearing the way for another aircraft to land. If the

tailhook does not grab the wire or the aircraft has performed a touch-and-go, then the aircraft rotates off the landing area and will be repositioned for another Mode I attempt or manual landing. This repositioning will not require the aircraft to return to marshal, but rather conduct a left-hand racetrack pattern at 1,200 ft AGL. At 4 to 6 nm behind the ship, the aircraft will be "hooked" back in to align with the EFB for another Mode I approach, if requested. CATCC controllers will have to build space into the sequencing of other aircraft conducting the CV-1 profile to fit in the bolter aircraft.

Having described the CV-1 profile and Mode I procedures, the author will now introduce how the aircraft carrier Precision Approach Landing System (PALS) components are certified for fleet use.

THE PALS CERTIFICATION PROCESS

Certifying aircraft carrier PALS equipment is a critical process that once complete, provides the fleet aviators and ship personnel with accurate and fully functional landing aid systems. Certification is defined as "a comprehensive check of the PALS for all of the designated modes of operation." Verification is a subset of certification and is defined as "a functional and alignment check to authorize continued use of the designated PALS modes of operation with specified PALS qualified aircraft" (NAVAIRINST 13800.11D). For the purposes of this paper, certification and verification concepts are synonymous. Accurate and fully functional landing aid systems imbue pilots and controllers with a high degree of confidence in the system and lead to a safer recovery environment. Examples of when certifications are required include: 1) after initial PALS installation or 2) after changes or modifications are made which affect aircraft control. NAVAIR is the primary point of contact for PALS, providing lead management and coordination responsibilities to include certifications/verifications of both shipboard and air station facilities (NAVAIRINST 13800.11D).

PALS certification efforts focus on the AN/SPN-46(V3), Link 4A datalink, CATCC procedures and equipment, and the ILM/ICLS. Ship interface equipment, such as the ship gyros, anemometer system, UHF radios, TACAN, and IFLOLS assist in the

certification process. Once testing is complete, a certification clearance is issued by NAVAIRWARCENACDIV through NAVAIRHQ (PMA-251) to the aircraft carrier that authorizes the use of designated PALS modes of operation. A clearance is valid for no more than 24 months for each ship and may include restrictions such as minimum ceiling and visibility, maximum/minimum wind over the deck conditions, specified glideslope, and deck motion limitations. The clearance will also list those type/model/series aircraft that can perform Mode I, II, and III approaches. Once the certification process starts, no aircraft (other than test) may attempt an approach to the ship until the certification is complete and a clearance has been issued. PALS certification targets the ship systems, not the test aircraft. Test aircraft are "groomed" for PALS work at NAS Patuxent River and are used as a truth source for testing. Therefore, any anomalies or problems associated with shipboard PALS can most likely be traced to the ship. This helps the PALS team focus their problem solving techniques.

The PALS certification team is generally made up of 4 to 6 test pilots, flight test engineers, and 2 to 3 instrumentation personnel. Test pilots and engineers may have varying operational experiences and backgrounds, but all are properly trained and qualified in PALS procedures. Three F/A-18A-F Hornet test aircraft are typically used to conduct certification; however, fleet F/A-18 aircraft may be substituted only after checkout flights confirm fully operational PALS systems. Test aircraft are fitted with unique instrumentation that allows the engineers to gather, reduce and report on data. The aircraft are also equipped with video cameras that record HUD video on 8mm cassette tapes. As part of the reporting criteria for PALS status, deficiencies are classified as Part I, II, or III and are delineated in the PALS clearance. Part I deficiencies affect the ability of the PALS to perform any mode of operation or jeopardize aircrew safety and must be fixed ASAP. Part II deficiencies highlight a degradation in the PALS system that is not quite as severe as Part I and should be corrected prior to ship deployment. Part III deficiencies are minor and need to be corrected prior to the next certification procedure.

PALS certification tests consist of three categories (CATs). CAT I testing does not involve flying. It is used by the engineers to ensure correct installation,

interconnection, interface, alignment, and performance of ship PALS components. This process normally takes two weeks to complete. CAT II testing follows CAT I and utilizes fixed or rotary wing test aircraft to determine basic radar tracking, system operation, and AN/SPN-46, AN/SPN-41, and IFLOLS alignment. It requires that there be little or no ship motion; therefore, it is usually completed to a carrier that is pier-side. CAT III testing consists of basic alignment, tracking and control, control program optimization, and touchdown dispersion / WOD envelope determination. CAT III procedures take about one week to complete. The time to complete the entire shipboard PALS evolution therefore takes about a month. The responsibility for completing CAT II and III testing lies with the Developmental Test and Evaluation Squadron (VX-23) stationed at NAS Patuxent River, Md.

Before PALS certification can commence, all test pilots and engineers participating in the exercise must read through and be familiar with a VX-23 PALS test plan. This test plan includes: background information and purpose of the test, description of the test aircraft, scope and method of test, program management and risk analysis. Test plans are revised periodically and are scrutinized by the squadron leadership to make sure they conform to NAVAIR and squadron standards. Safety is paramount. Prior to detaching to the aircraft carrier under the certification process, the test aircraft are taken through a rigorous bevy of ground and airborne tasks. Ground tasks are completed at NAS Patuxent River and consist of ACLS, datalink connectivity and discrete display tests, and radar beacon check-out. Airborne tasks consist of ensuring proper operation of the auto throttles, AOA verses airspeed checks, radar beacon tracking and glidepath control. In addition, the test team will conduct closed-loop and open-loop response tests to validate or troubleshoot AFCS functionality. The goal is to leave NAS Patuxent River for the aircraft carrier with proven and reliable ACLS aircraft.

Execution of the test plan begins with sending the flight test engineers to the aircraft carrier for initial CAT I testing. Once complete, CAT II and III testing commences with VX-23 test pilots working in conjunction with CATCC personnel and the flight test engineer team to gather PALS data as noted above. CAT III ACLS testing is one of the more dynamic, fun and rewarding events that a test aircrew can complete.

CAT III testing begins with the pilots flying "level legs" under the supervision of the CATCC controllers. Level legs consist of flying a left-hand racetrack pattern around the ship at a constant altitude. This will help the engineers verify the basic pedestal alignment of the AN/SPN-46. Next, with the constant supervision of the CATCC controllers, Mode I approaches begin. The test aircraft are positioned approximately 6 nm from the ship on the EFB. From there, AN/SPN-46 acquisition occurs and the aircraft flight controls are coupled to the ship following the procedures previously described above. Just prior to and along the glideslope, correlation calls are made by the test pilot to CATCC and the test engineers. Correlation calls serve to compare SPN-41, SPN-46, and IFLOLS indications of what the test pilot observes from the cockpit. A correlation example between the SPN-41 and SPN-46 and a depiction of the PALS pattern is located in Figure A-5. These correlation calls are then superimposed over the data received by the test engineers. It is from this data that the PALS equipment is modified to reduce errors in order to produce desired results, specifically a very smooth approach to a 3-wire landing. Before certifying a carrier, the test team would like to have a high confidence that the Mode I approach will lead to a hook touchdown point of 230 ft. with a longitudinal dispersion of +/- 24 ft and a lateral dispersion of +/- 5 ft of landing area centerline.

Test aircraft fly touch-and-goes during the PALS pattern to maximize testing per tank of fuel. Following Mode I touchdown, the test aircraft is returned to the pattern for another Mode I approach and the test pilot reviews the last pass with the CATCC controllers and engineers. Test aircrew use a Pilot Quality Rating (PQR) to assess each pass for the engineers. This data will help in determining if there are any undesirable effects during the approach that need to be addressed. The PQR scale is listed in Figure A-6. Flight continues until the test aircraft is low on fuel. A typical PALS event will last three hours with three hours rest before the next event. This rest period gives the pilots and engineer/CATCC team a chance to debrief individual passes and recommend a further course of action. CAT III testing is normally done without any other aircraft traffic in the carrier landing pattern. Two to three test aircraft can be flying in the PALS pattern at one time to maximize the gathering of touchdown dispersion and WOD data

per event. A major strength of the ACLS and Mode I operations is the fact that there is a dedicated and knowledgeable core group of test pilots, engineers and instrumentation personnel that test and certify the carrier landing systems on a routine basis to ensure proper operation and technical procedures are being administered, translating into a high confidence in the ship recovery personnel and airwing pilots in its use.

The following paragraphs discuss the effectiveness and viability of the ACLS system and Mode I approaches by presenting not only more strengths, but a pertinent weakness as well.

CHAPTER IV. CURRENT ACLS MODE I EFFECTIVENESS

GENERAL

There are several enhancing characteristics of the ACLS and Mode I systems, which the author now presents. A major strength of the Mode I system is rooted in Operational Risk Management (ORM). ORM is a process that includes: 1) Identifying hazards and risks, 2) Making risk decisions, 3) Implementing controls, and finally, 4) Evaluating the results and making recommendations. ORM is widely used throughout the military and quite extensively in naval aviation due to the inherent risk in the job. Mode I approaches are a successful and proven risk mitigation tool that can be implemented by squadron and airwing commanders to safely return aircrew to the carrier. Perhaps this is no more relevant than in our current wartime environment, conducting current missions in our ongoing War on Terror. Typical F/A-18 missions last in excess of three hours. Oftentimes the mission planning for these events was worked on for hours prior to the flight by the same aircrew that are scheduled to fly that mission. Extreme stress, fatigue, and even vertigo are common detrimental factors that may affect the aircrew and influence their performance and are considered operational risks.

Testing has also been completed on Mode I effectiveness with various forms of aircraft system battle damage and the results are encouraging. When returning to the ship for recovery, a Mode I approach might very well be a safer alternative to manual flight, given the oftentimes dynamic and dangerous circumstances that surround night time or reduced ceiling/visibility recoveries. The last thing that any strike aviator would want would be to launch into foreign territory, conduct administrative and operational flight responsibilities, release ordnance under heavy duress, and make the long transit back to the ship only to hear that the weather has gone down to minimums and have to shoot an instrument approach to a pitching carrier deck. This is the nature of the business, and yet the Mode I can alleviate these problems and potentially save the lives of aircrew and/or the destruction of aircraft assets.

Another strength of the Mode I system is the safety redundancy and communications associated with an approach. Mode I approaches are not flown in a

vacuum, that is to say the CATCC controller, LSO and tower all have authority to advise the pilot to disconnect the autopilot and discontinue an automatic approach if safety dictates. Downgrading from an auto to a manual approach is reasonable, but the pilot would like to be informed early in the approach procedure whether to expect an automatic approach or not. Therefore it is important that the request for a Mode I approach be made in marshal and that the airborne aircrew are kept advised of any status changes in the ACLS. The aircraft can also provide feedback to the controllers, LSO or pilot in that if the aircraft is not capable of flying the approach, then it will not allow proper commands to be sent such as an ACL RDY discrete or CPL option.

The ACLS is touted as an all-weather approach system. From operational experience, the author would concur that the ACLS equipment is accurate and reliable when used during precipitation or reduced ceiling/visibility conditions. I have never experienced any problems with the ACLS due to weather. A major advantage to having the all-weather capability stems from the previous safety discussion above. Arriving at the back of the ship in VFR weather is obviously more preferable than to be in an obscured or degraded environment. Our current OPNAV 3710, a document that governs naval aviators conduct, sets single piloted weather minimums at 200 ft and 1/2 nm visibility. Coincidentally, these are the minimums for an ACLS approach with ILM provided by the SPN-41. Unless allowed to continue the approach to a lower altitude by operational necessity, as granted by the Captain of the carrier, this is the lowest we may legally fly. A go-around must be initiated if the landing environment is not in sight, similar to a civilian land-based approach. This applies to all types of carrier approaches, even Mode I. It is very rare to have weather below minimums during a recovery, but it does happen from time to time. It is this "near weather minimum" environment in which the author believes the ACLS does the most good.

The use of the Mode I system is not only beneficial for the pilots, but for aircraft carrier tactical operations as well. Carriers are somewhat limited on occasion as to how far they may transit during launch and recoveries. This is due to the need for adequate wind over the deck requirements to safely launch and recover aircraft. During recovery, a main concern is the closing speed between the aircraft and the carrier. Without the

required headwinds (18 knots for a full flap F/A-18A-D), the arresting gear would take significantly more strain and possibly damage the system. The carrier's need to "make" their own headwind at times results in steaming in a straight line for miles until recovery is complete. Therefore, it is vital that the airwing aircraft make an arrestment on their first pass because the ship may be limited in the amount of sea space it requires to make the adequate headwinds. The number of aircraft that trap on the ship on the first pass is called the first pass boarding rate and is a metric used by the ship and airwing to measure recovery efficiency. Successful Mode I approaches would tend to increase the boarding rate, decrease the bolter or missed approach rate, and therefore reduce recovery time and sea space for the carrier. An increased boarding rate would also allow for quicker turnaround time in order to perform aircraft maintenance and prepare the aircraft for another mission. While there are some valid strengths to the continued implementation of Mode I approaches, there is a valid weakness that needs to be constantly addressed.

The main weakness in the ACLS is the reliability over time. Between PALS certification testing, the carrier and the assigned airwing typically conduct two cruises and two full sets of workups. Training commands and the FRS squadrons routinely use the carrier as well to carrier qualify their new pilots. This translates into a very heavy workload for the PALS equipment, which is subjected to extreme temperatures and high tempo working environments at times. Even with preventative and routine maintenance being conducted on schedule, there is always the potential for problems to surface. Not all ships have issues with the ILS, ACLS, or IFLOLS during work-ups or cruise; however, there are exceptions. Most notably, the *USS Reagan* and *USS Enterprise* were experiencing equipment problems that led to correlation discrepancies in the spring of 2006. The *USS Reagan* was deployed to the Persian Gulf at the time, while the *USS Enterprise* was in the process of conducting work-ups. Both aircraft carriers had passed PALS certification tests within the last year. The aircrew and CATCC controllers noted the problems and looked to NAVAIR for some answers, as the ACLS status directly affected the safe and expeditious recovery of aircraft. NAVAIR test pilots and engineers were dispatched to the ships and once the problems were diagnosed, they were repaired and normal recovery operations continued.

To combat this potential unreliability, embarked aircrew and CATCC personnel must accurately note the problems so ship personnel or NAVAIR representatives can quickly ascertain the degree of difficulty in getting the PALS back up online. The means to complete this is through a CATCC PALS discrepancy form. These forms are found in the CATCC control room and are a good place to start recording pertinent information. The form should provide for a quick and accurate diagnosis of the problem. It is imperative that NAVAIR personnel be notified if there are any continuing problems. PALS issues generally do not go away on their own, and the aircrew deserve valid correlated systems during carrier recoveries. Timely correction of a problem will further instill a high degree of PALS confidence in the aircrew and ship personnel. It is worth noting that over the last ten years, only two instances of adverse flight control characteristics while under the control of Mode I ACLS were documented with the Navy Safety Center, both attributed to faulty R-DG units (Naval Safety Center, 2006). The author has found that there were more flight control discrepancies noted by aircrew, but they went unreported. The discrepancy reporting procedure has proven its effectiveness when used, yet it must be utilized more often. Proper maintenance and reporting procedures also apply to the squadron personnel and the upkeep of their aircraft. Mode II IFF, datalink, beacon, AFCS, and ATS systems must be routinely exercised and problems noted early for prompt maintenance action.

One potential problem worth noting, not necessarily a weakness, is the effect the dynamic motion of the carrier may have on the ACLS and aircraft recovery due to weather or sea state conditions. Under extremely high flight deck magnitude or rates in pitch, roll and lateral translation, the Mode I system may not be able to affect a safe landing for the F/A-18. Pilot, LSO, and CATCC monitoring of the system and the approach is crucial. In this case, a downgrade to a manual pass would be required. This may adversely affect aircrew that have acquired a heavy reliance on the Mode I system for past recoveries. Their approach should be monitored with increased vigilance. This may also give credence to the LSO NATOPS with regards to monitoring of pilot proficiency in light of multiple continuous Mode I approaches. Having highlighted

ACLS past and present effectiveness, the author would like to discuss the future of automatic carrier landings and what it implications there are to naval aviators.

CHAPTER V. THE FUTURE OF AUTOMATIC CARRIER LANDINGS

GENERAL

With all the great benefits of using a highly effective automatic landing system in the F/A-18 as described in the previous paragraphs, perhaps one would think that naval aviators would use it all the time--especially on combat deployments. Table 2 identifies aircraft carriers that have recently participated in Operations Enduring or Iraqi Freedom. This table highlights the number of F/A-18A-F Mode I approaches under Case III weather conditions that were attempted and completed versus Mode II attempted while in support of high tempo combat operations. The reasons for failure to complete an attempted Mode I approach include: 1) no pilot ACLS indications in the cockpit, 2) the ship unable to couple up to the Hornet AFCS, or 3) the pilot disengages the AFCS or LSO/CATCC controller advise disengagement for safety reasons. As one can see from the data, this happens about 50% of the time. The important point illustrated in the table, is the fact that Mode I automatic carrier landing attempts/requests constitute a very small percentage (about 2%) of all Case III approaches flown. This trend is prevalent throughout the carrier navy for airwings that are either on deployment or work-ups. The following paragraphs discuss reasons why this trend exists today and what the future holds for squadron pilots.

Table 2. F/A-18 A-F Six-Month Approach Information for Aircraft Carriers Supporting Operations Enduring and Iraqi Freedom
(NAWCAD Message Traffic)

DESIGNATION	CARRIER NAME	Mode I Attempted	Mode I Completed	Mode II Attempted
CVN-70	USS VINSON	113	51	3,272
CVN-71	USS ROOSEVELT	13	6	1,070

A major reason why more Mode Is are not flown is rooted in the traditions of carrier naval aviation. For many years, a pilot's skill was measured by how well he controlled his aircraft in the carrier environment. To some extent, that feeling is alive and well today. Carrier aviators pride themselves on the grades received after each successful arrestment. Grades are posted in each squadron ready room for all to see. Every four weeks during a deployment, awards are handed out to those aircrew who have achieved a milestone in the number of landings in their career or on a specific carrier. Highly coveted awards are distributed to those carrier aviators who have the highest landing grade average. This tradition helps foster individual excellence and team building and is a critical part of each squadron's morale. The Mode I approach, albeit arguably the safest type of approach during Case III operations, does not garner a grade. It is seen as a "free pass" of sorts because the pilot did not manually fly the aircraft to touchdown. Competitive spirit drives a pilot to weigh the consideration of flying a Mode I with their grades hanging in the balance, for another pass may propel them into the top ten in the airwing. Flying too many Mode I approaches may possibly be seen as grounds for ridicule amongst colleagues. It is not uncommon to see F/A-18 squadron commanders implement a policy of not allowing first cruise aviators to fly Mode I approaches. Another factor that may trounce the traditions of naval aviation is the introduction of unmanned aerial vehicles to the carrier. While this innovation may be a few years away, it is already having a direct impact on the fabric and nature of carrier operations and has aviators questioning whether the Joint Strike Fighter may indeed by the last manned combat aircraft ever made for the U.S. inventory. The manned combat platform may be giving way to these technological marvels.

Another major reason why aircrew may not fly many Mode I approaches is due to reduced confidence in the ACLS or malfunctioning ship/aircraft equipment. At times throughout work-ups or cruise, aircrew may notice the ILS/ACLS/IFLOLS correlation has skewed on a number of approaches. Perhaps aircrew perceive that the ACLS has been degraded in one form or another. These perceptions drive a reduction in requests for a Mode I approach because aircrew feel the system will not get them to a very good start position behind the ship or worse yet, will drive the AFCS to put the pilot in a

dangerous situation near the ramp – one that he might not be able to escape. These are all valid concerns, but stress the importance of good communication flow between the airwing, CATCC, and NAVAIR. If the system has a problem, it needs to be addressed and as was mentioned before, there are steps in place to make it happen.

The last major reason that aircrew do not utilize Mode I approaches is due to pilot night proficiency and currency requirements placed on them by the LSO NATOPS. Figure 6 shows an abbreviated night currency matrix for carrier qualified pilots. This qualification matrix drives the requirements for aircrew given the number of days since their last night carrier arrestment. The important point to highlight is that if a pilot does not conduct at least one night arrestment every week, he must conduct one arrested landing during the day prior to his night flight. When that pilot flies at night, he is not permitted to fly a Mode I to regain currency – it must be a manually controlled landing. This does not happen very often over the course of a cruise, as squadron commanders track this very carefully; however, it does delineate when a Mode I may not be flown. Pilot proficiency may also be a limiting factor for use of a Mode I approach according to LSO NATOPS in that it may put an artificial cap on the number of consecutive Mode I approaches allowed by any one pilot. That decision will ultimately rest with the airwing LSO and Commander based on the individual pilot's past performance in the landing environment. The restrictions placed on aircrew by LSO NATOPS and the rationale behind it may indeed change with the advent of new technology in the form of JPALS and the future integration of J-UCAS to carrier recovery procedures.

JPALS

JPALS is a landing system that utilizes GPS, INS, and network technologies in order to safely guide an aircraft to a precision landing. JPALS is in the TD acquisition phase, with Milestone B and SDD contract award planned in FY08. Once fielded, JPALS will replace legacy radar-based precision landing systems and will result in life cycle cost reductions. JPALS can be used to perform automatic carrier landings.

DAYS SINCE LAST NIGHT CURRENT	REQUIREMENTS PRIOR TO A NIGHT LANDING OR NIGHT CAT SHOT[6, 7, 9]	WEATHER	DECK	DIVERT FIELD	CURRENCY REQUIREMENT
1-7 days	None	Ships mins	ALL conditions	N/R	1 arrested landing (T/G or arrested)[10]
8-14 days	1. One day landing that day to include a day cat shot OR 2. Two day landings, one of which shall be arrested, one day cat shot and not less than one hour of flight time within a 36 hour period prior to the night landing	TACAN mins	ALL conditions	N/R	1 arrested landing (T/G or arrested)[10]
Dual F/A-18A-D and F/A-18 E/F qualification currency[11]	3. None, if the aircrew has had one night arrested landing in the other series in the previous 7 days.	N/A			

Figure 6. Abbreviated Night Currency Requirements for F/A-18 Aircrew (LSO NATOPS)

Datalink is the means by which the sea-based system operates through a technique known as Shipboard Relative GPS or SRGPS. In SRGPS, the aircraft will compare its GPS/INS position with the location of the glideslope as provided by the ship's GPS over datalink. As the aircraft approaches the ship, the relative GPS error difference is minimized to the point where a very accurate determination of relative position can be made using real-time kinematic (RTK) GPS techniques. Future JPALS capability with other systems may also be able to perform many of the functions now relegated to CATCC personnel such as marshal, marshal instructions, airspace management and sequencing aircraft on approach, and will be designed to work in all-weather and some electro-magnetic jamming environments. In April 2001 aboard the *USS Theodore Roosevelt*, the first successful tests were conducted using the SRGPS system. Ten automatic carrier arrestments were completed with an F/A-18 test aircraft from VX-23. The hook touchdown point dispersion met the strict operational requirements for automatic landings at sea. Initially, JPALS will be integrated in the current CV Airwing aircraft and the JSF. JPALS will impact the fleet because it is the new and improved mode of choice for automatic landings, and it is the author's contention that full integration of the JPALS will drive the request for more automatic carrier landings in the future.

N-UCAS

Navy UCAS is a program that originated in 2003 and falls under the auspices of the Department of Defenses' DARPA and the U.S. Air Force and Navy. The J-UCAS is a combat vehicle that will be able to launch and recover from the aircraft carrier and provide detailed ISR capabilities and precision strike. On February 23rd-29th , 2004 aboard the *USS Harry Truman*, a Northrop Grumman N-UCAS mission control demonstration was completed utilizing equipment on an X-47B surrogate, a specially configured Beechcraft King Air. This test successfully demonstrated the ability of the control equipment to operate within the CATCC and carrier landing environment. Both Northrop Grumman and the Boeing Corporation are currently competing for the N-UCAS contract and have received millions of dollars to continue research and development. Figure 7 shows the latest aircraft demonstration models from both companies. The ultimate goal is to integrate unmanned vehicles into the world of manned vehicle operations with the highest standards of efficiency and safety in order to promote the Chief of Naval Operations goal of "aligning USN/USMC aviation recapitalization plans, to include the development of TACAIR integration, Helicopter, and UAV Master Plans" (CNO Guidance, 2006). The N-UCAS impact on the carrier airwing, flight operations, and CATCC controllers is predicted to be minimal. Unmanned and manned aircraft will marshal behind the carrier and fly the CV-1 approach or perhaps a new modified pattern will be designed that takes full advantage of the airwing JPALS/ACLS automatic landing characteristics. It is the author's contention that the full integration of the N-UCAS into the airwing will also drive a request for more automatic carrier landings from manned platforms.



Figure 7. The Northrop Grumman X-47B and Boeing X-45A J-UCAS
(Photo Courtesy of the DARPA website)

CHAPTER VI. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

At the beginning of this paper, the author asserted that the Mode I fully Automatic Carrier Landing System capability is extremely vital to the safe and expeditious recovery of the F/A-18A-D Hornet aircraft onboard the modern aircraft carrier and will continue to be a valuable asset in 21st century naval aviation. Through a description of the Hornet and carrier ACLS components, Mode I approach and PALS procedures, the author has attested to the effectiveness of this system in the reduced ceiling and visibility (Case III) environment. In looking at the future of the automatic carrier landings, the author has provided an argument for the continued use of these systems by the naval force and both addressed future tactical implications and challenged squadron policies.

Carrier aviation is currently undergoing a transformation. Older aircraft are being replaced by newer, more technologically advanced systems. Joint interoperability is the new buzzword for strategic, operational, and tactical success on the battlefield. The United States Navy must be on the forefront of this transformation, supplying new tactics, techniques and procedures to more effectively and efficiently conduct operations. JPALS, the Joint Strike Fighter and N-UCAS technologies are the future of naval aviation and as an organization, the Navy must be ready to adapt to their arrival in the fleet. The naval carrier aviation business may be approaching the tipping point in which fully automated landings become the rule as opposed to the exception. Change is not always easy and oftentimes it is hard to overcome conventional ways of doing things; however, our organization must continue to think critically about our processes and how we might be able to make them better. The author joins many of his contemporaries who do not like the idea of giving up control of our aircraft during recovery operations at the carrier; however, if required to increase efficiency, enhance safety, and make our combat force more effective - then giving up control may be the best course of action. Finally, in this world where all federal budgets are extremely tight, and every dollar must be stretched to the maximum, the author offers the following question: Why would our

organization not continue to support a landing system that has the great benefit of giving our aircrew and their aircraft every chance possible to return home safely to their ship, home, and loved ones? The author firmly believes the automatic carrier landing feature is worth every penny.

RECOMMENDATIONS

The author submits the following recommendations in order to promote the continued use of the ACLS Mode I and to help ease the inevitable transition process to more automatic aircraft control in carrier aircraft recovery.

1. Implement a Phased Concept for Current and Future ACLS Utilization.
    a. Phase I
        i. Start at the present time and continue until JPALS is functional on all aircraft carriers.
        ii. Create a command climate in the squadron that promotes the increased use of Mode I approaches, even for new fleet pilots. This can be done by commanding officers and department heads exercising the system more on cruise or work-ups.
        iii. Increase ground, simulator and airborne training on Mode I techniques and procedures.
        iv. Fly all VFR day approaches manually.
        v. Fly a majority of night time and bad weather approaches using Mode I procedures.
        vi. Maintain the currency and proficiency requirements as outlined in LSO NATOPS.
        vii. Continue to practice day and night FCLPs for fleet and FRS pilots prior to work-ups and deployments.
        viii. Brainstorm the design of a new CV-1 approach that capitalizes on the efficiency of JPALS.

b. Phase II
    i. Will begin when JPALS fielded on all aircraft carriers.
    ii. Capitalize on the new JPALS system by:
        1. Reducing the requirements for night time currency and proficiency for all fleet pilots.
        2. Fly only some day VFR approaches manually.
        3. Fly all bad weather and night time approaches using JPALS Mode I procedures and new CV-1 approach.
        4. Continue to train FRS and Fleet aircrew on ACLS/JPALS procedures.
        5. Tailor day/night FCLPs. This will constitute a large cost savings for the Navy with a reduction in training flight hours, yet an increase in safety through the new JPALS approach system.
c. Phase III
    i. Will begin with full integration of JSF and N-UCAS platforms into the carrier airwing operations.
    ii. All approaches will be JPALS fully automatic.
    iii. All FRS and Fleet aircrew will be fully versed in the new JPALS techniques and procedures.
    iv. Naval aviation will have become a culture still rich in tradition, but adaptive to new technology and cognizant of the increase in safety and potential decrease in operating costs of the JPALS approach format.

2. NAVAIR should continue to research, design and test JPALS to ensure the highest of quality, redundancy and safety margin. New updates should be pushed to the Fleet as quickly as possible.
3. Fleet squadron policy (SOP) should dictate that any problems with any landing aids on the carrier or Mode I flight control should be reported immediately to CATCC and then to NAVAIR if the problem cannot be fixed.
4. Master jet Naval Air Stations should have properly working ACLS and ILS systems for use by fleet aviators. Approach controllers at NAS should be properly trained and even request pilots to fly ACLS Mode I approaches for training and to routinely exercise the systems. Problems should be reported in a timely fashion.
5. F/A-18 squadrons should continue to monitor and apply correct maintenance procedures for the upkeep of ACLS, ILS, and IFF components.

BIBLIOGRAPHY

BIBLIOGRAPHY

"ARCINC and Raytheon Form a Team to Pursue Expanding JPALS Program", *ARCINC News*, (http://www.arcinc.com/news/2005/04-25-05.html), 16 February 2006.

"Automatic Carrier Landing System – Chapter 9", *Integrated Publishing*, (http://www.tpub.com/content/aviation/14030/css/14030_205.htm), (pp. 1-7), 20 July 2006.

Budde, Mark, (MAJ), Naval Safety Center F/A-18 Analyst, email to Author, dated 7 March 2006.

Carrier Suitability Testing Manual, original dated 3 April 1991 with Rev 1 dated 16 November 1993 and Rev 2 dated 30 September 1994.

CV NATOPS Manual, Issued by Authority of the Chief of Naval Operations and Under the Direction of the Commander of NAVAIR, 21 October 1999.

"DARPA Awards Funding for X-45 Portion of Joint Unmanned Combat Air Systems", Defense Advanced Research Projects Agency, 11 July 2005.

"DARPA Awards Funding for Joint Unmanned Combat Air Systems' X-47B", Defense Advanced Research Projects Agency, 20 October 2005.

Etz, Erik, (CDR) and Benner, Robert, "CV, CVN, NAS Precision Approach and Landing System (PALS) Verification/Certification Test Plan", NAS Patuxent River, Md., dated October 2005.

"Joint Precision and Landing System (JPALS) Precision Approach and Landing Capability (PALC)", *Global Security*, (http://www.globalsecurity.org/military/systems/sircraft/systems/jpals.htm), 16 February 2006.

Luccio, Matteo and Colby, Glenn, "Navy Proves Hands-Off Touchdown", *GPS World*, Vol. 12 issue 8, p36, August 2001.

NATOPS Flight Manual Navy Model F/A-18 A/B/C/D 161353 and Up Aircraft, A1-F18AC-NFM-000 dated 15 December 2000 with Change dated 15 October 2003.

NATOPS General Flight and Operating Instructions 3710.7T, Department of the Navy, Office of the Chief of Naval Operations, 01 March 2004.

NATOPS Landing Signal Officer Manual, NAVAIR 00-80T-104, dated 15 December 2001.

NAVAIR Instruction 13800.11D, "Procedures and Responsibilities for Certification and Verification of CV/CVN Precision Approach and Landing Systems (PALS), NAVAIR PMA-251, NAS Patuxent River, Md., 02 August 2001.

"NAVAIR JPALS Program Schedules 2nd Industry Day for FY06 Procurement", *FedSources* Website Article, (http://www.fedsources.com/about/fsinews/mktflash_072205.asp), 16 February 2006.

(Naval Message), Quarterly PALS Status Report First Quarter CY 05// *USS Theodore Roosevelt*, NAWCAD, NAS Patuxent River, Md., 13 April 2005.

(Naval Message), Quarterly PALS and ATC Equipment Status Report for 4th Quarter, NAWCAD, NAS Patuxent River, Md., January 2005.

"Northrop Grumman Demonstrates System for Controlling Unmanned Aerial Vehicle Missions from Aircraft Carriers", *Primezone News Wire and Multimedia Distribution*, (http://www.primezone.com/newsroom/news_releases), 15 June 2004.

Patterson, John, B., "Joint Precision Approach and Landing System (JPALS): Making High-Risk Aircraft Operations Safer", *DSP Journal*, (www.dsp.dla.mil), July 2002.

Reynish, William, "JPALS: Not Just LAAS in Navy Uniform", *Aviation Today*, (http://www.aviationtoday.com/cgi/av/), 16 February 2006.

Schrum, Brian, "Bad-weather CV Approaches", *Approach*, Naval Safety Center, Norfolk, Va., July 2003.

"U.S. Navy – A Brief History of Aircraft Carriers, Part IV", Naval Historical Center, (http://www.chinfo.navy.mil/navpalib/ships/carriers/histories/), 20 July 2006.

USS Enterprise CVN-65 Carrier Airwing One (CVW-1) LSO Guide, NAS Oceana, Va., dated September 2003.

APPENDIX A

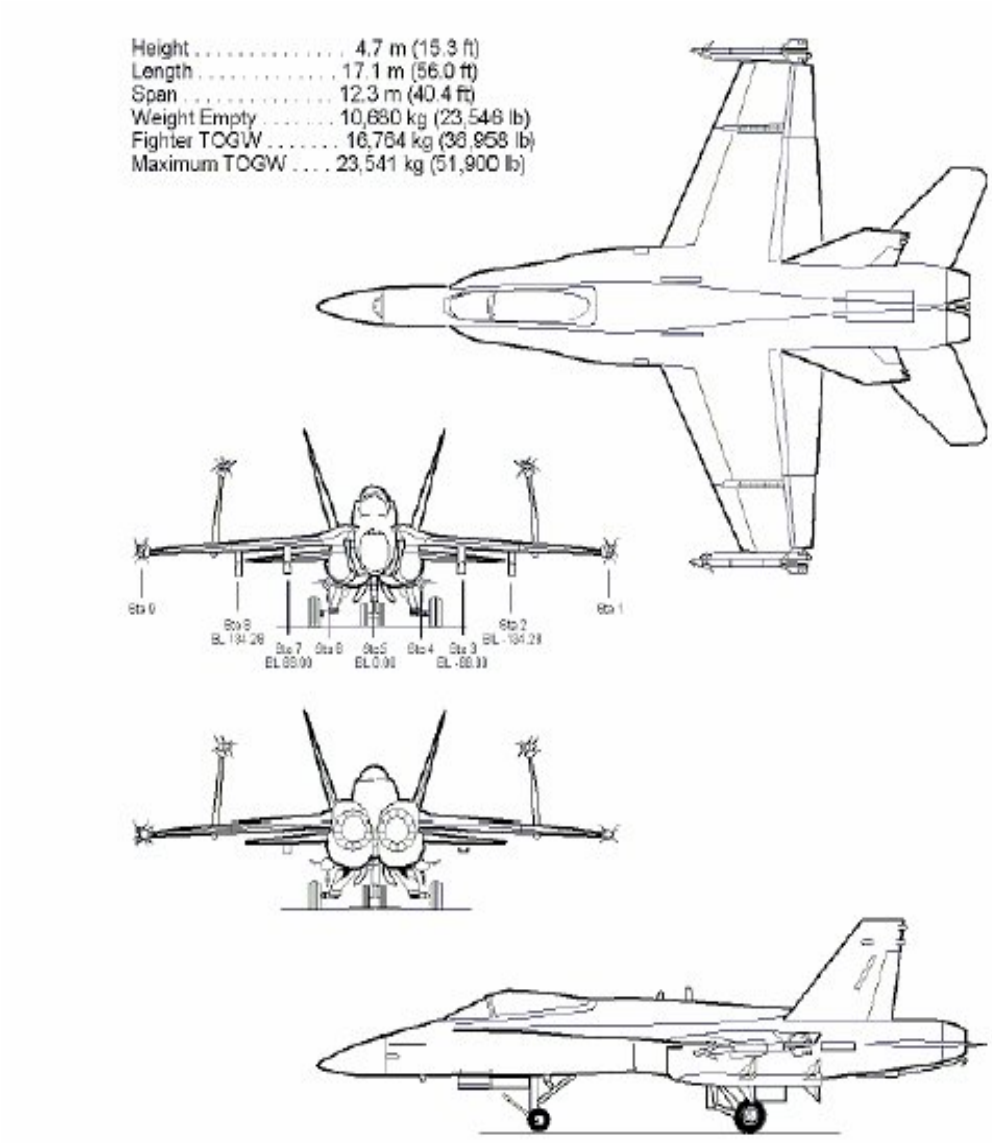


Figure A-1. The F/A-18A-D Hornet



Figure A-2. Front Seat F/A-18A-D Cockpit Displays

(Photo Courtesy of Mr. Randy Hepp)



Figure A-3. Approaching the Landing Area at Approximately ¾ nm
(Photo Courtesy of VX-23 Archive)



Figure A-4. Approaching the Landing Area Just Prior to Command Freeze
(Photo Courtesy of VX-23 Archive)

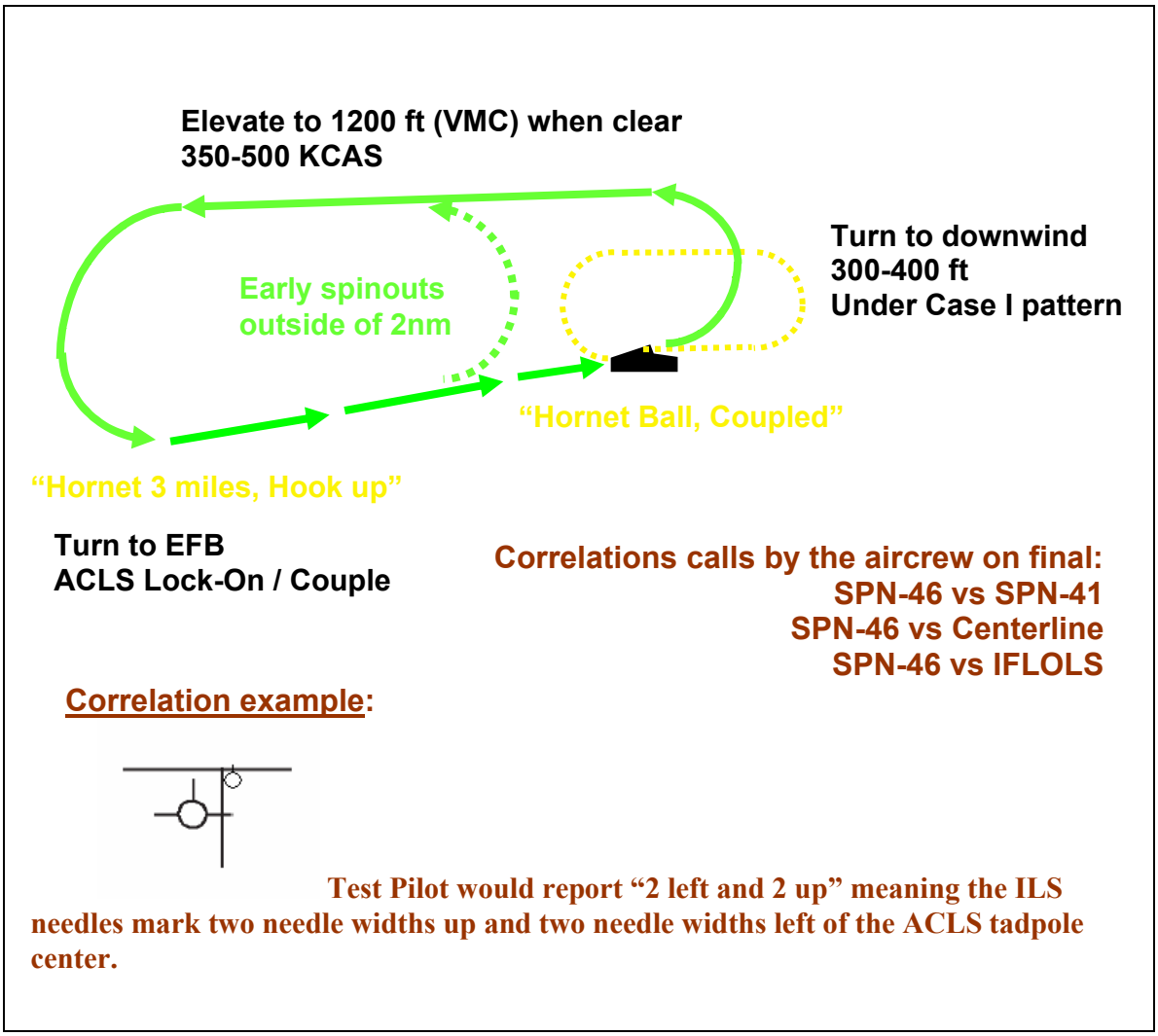


Figure A-5. The PALS Pattern and Correlation Example

(Diagram Courtesy of VX-23 Carrier Suitability Department)

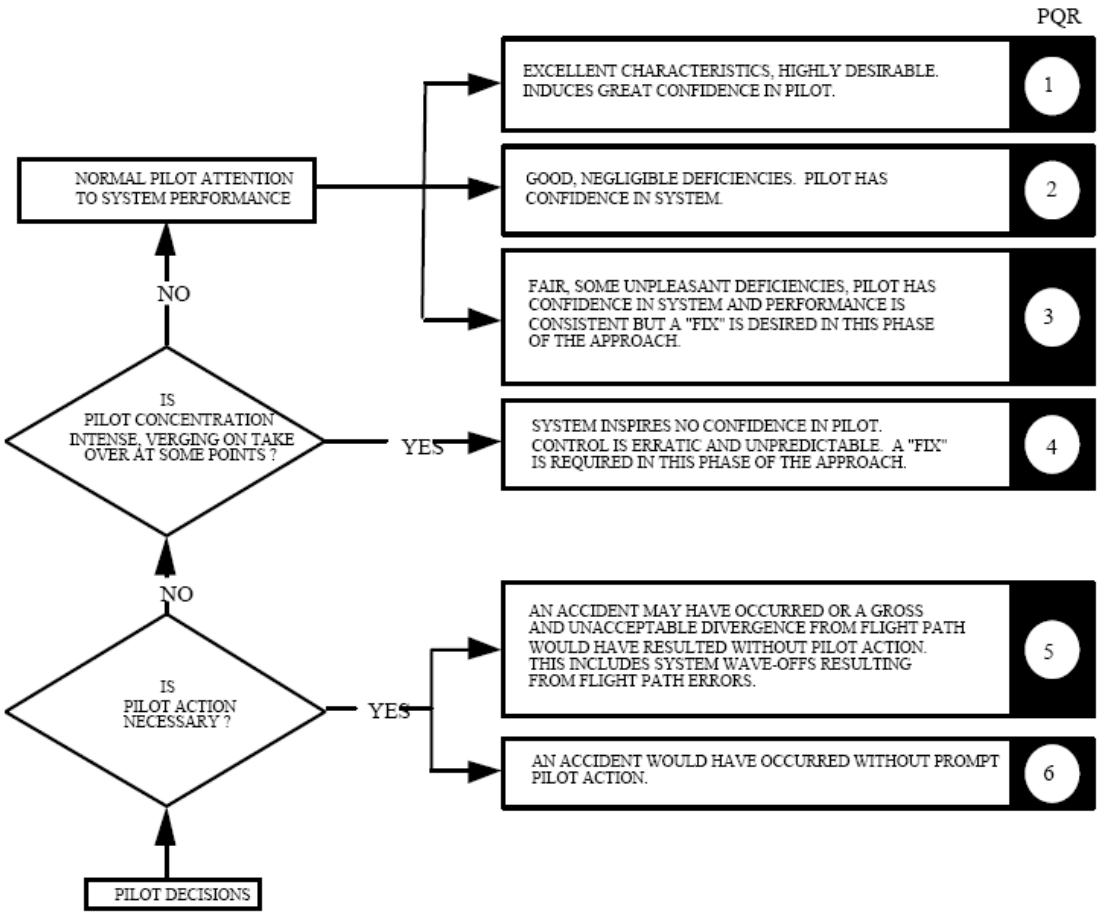


Figure A-6. The PALS PQR Rating Scale

(VX-23 PALS Test Plan)

VITA

LCDR Brian T. Schrum was born and raised in Fond du Lac, Wisconsin. He graduated from L.P. Goodrich in 1992 and received an appointment to the United States Naval Academy that same year. He graduated with merit from the USNA in 1996, majoring in Political Science. Upon graduation, he was commissioned an Ensign in the Navy and reported to Aviation Preflight Indoctrination (API) in NAS Pensacola, Fl to start his formal Navy flight training. In June 1999 he reported to NAS Lemoore, Ca with VFA-125 for Fleet Replacement Training in the F/A-18A-D Hornet. He completed Hornet training in April 2000 and was assigned to the VFA-83 *Rampagers* stationed at NAS Oceana, Virginia. LCDR Schrum made two Mediterranean/Persian Gulf cruises with the squadron onboard *USS George Washington* (CVN-73) from 2000-2002 in support of Operations Southern Watch in Iraq and Enduring Freedom in Afghanistan.

In August 2003, LCDR Schrum reported to the United States Naval Test Pilot School (USNTPS) as a member of Class 125. He completed the USNTPS in July 2004 and was assigned to Test and Evaluation Squadron Two Three (VX-23) as an F/A-18 Hornet and Super Hornet developmental test pilot. While at VX-23, LCDR Schrum was project officer in the Ordnance Support Team (OST) department where he worked on various weapon separation, systems, performance and flying qualities programs. He was later assigned to the Carrier Suitability department where he worked on three Precision Approach and Landing System (PALS) detachments and Shake/Rattle/Roll ship suitability flights as LSO and pilot. LCDR Schrum is currently enrolled in the Army's Command and General Staff College for a year of Joint Professional Military Education.

LCDR Schrum has over 1400 total flight hours in more than 20 different fixed and rotary winged aircraft and has accumulated over 320 carrier arrested landings on five aircraft carriers. He currently resides on post in Ft. Leavenworth, Ks with his wife, Nancy and their daughter, Leah.