



NAV  AIR

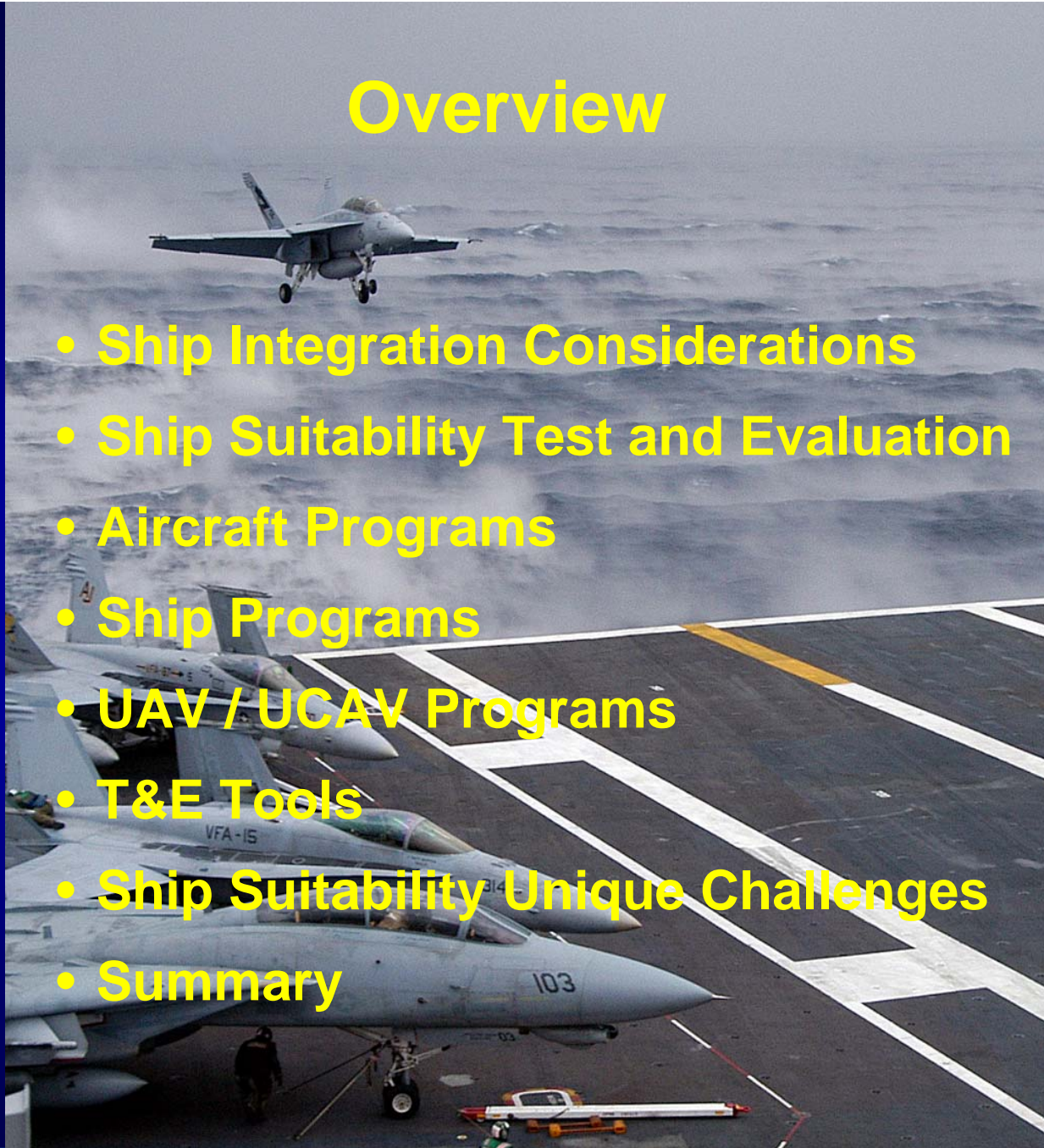
Ship Suitability Test and Evaluation – Preparing for the Future

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Naval Air Warfare Center, Patuxent River, MD
14 March 2007



Overview

- Ship Integration Considerations
- Ship Suitability Test and Evaluation
- Aircraft Programs
- Ship Programs
- UAV / UCAV Programs
- T&E Tools
- Ship Suitability Unique Challenges
- Summary





Ship Integration Considerations





Design Considerations

- All major aircraft design considerations are driven by requirement to operate on a ship
 - Wingspan / rotor span
 - Aircraft length and height
 - Control surface sizing and flight control system
 - Landing gear
 - Cockpit design
 - Weapons carriage locations
 - Servicing/Maintenance interfaces
 - Support equipment
 - Materials (corrosion / fire)





Environmental Considerations

- **Adverse operating environment**

- Ship's Motion
- Ship's Airwake
- Confined Area
- Corrosive Hazards
- Acoustic Hazards
- Ingestion Hazards
- Electromagnetic Hazards





Ship Suitability Test and Evaluation

- **Provides the engineering people, processes, and facilities to conduct tests to determine air vehicle compatibility with the shipboard operating environment to include**
 - Launch and Recovery Equipment
 - Air Traffic Control and Landing Systems
 - Shipboard facilities
- **Located at the Naval Air Warfare Center, Patuxent River, MD**
- **Three Branches within the Integrated Systems Evaluation, Experimentation, and Test Department**
 - Fixed Wing
 - Rotary Wing
 - Air Traffic Control and Landing Systems
- **Work closely with all engineering and logistics competencies and other countries**





Fixed Wing Ship Suitability T&E



- **Charter**

- Determine the performance and compatibility of manned and unmanned conventional and V/STOL aircraft, and aircraft systems in the shipboard operating environment for all classes of aircraft carriers, amphibious ships, and from advanced airfields

- **Primary areas of T&E expertise**

- Aircraft low airspeed flying qualities and performance
- Launch and recovery structural suitability
- Aviation facility requirements
- Launch and recovery envelope development



Shake, Rattle, and Roll





Rotary Wing Ship Suitability T&E



- **Charter**

- Determine the performance and compatibility of manned and unmanned rotorcraft, and rotorcraft systems in the shipboard operating environment for all classes of aircraft carriers, amphibious ships, aviation capable ships

- **Primary areas of T&E expertise**

- Rotorcraft flying qualities and performance
- Aviation facility requirements
- Launch and recovery envelope development (Dynamic Interface)





DI Testing

- Over 20 different ship classes



- Over 15 different helicopter types





Air Traffic Control and Landing Systems T&E



- **Charter**

- Develop, test, and evaluate shipboard, shore based, and satellite-based Air Traffic Control and Landing Systems (ATC&LS) and related aircraft avionics systems for manned and unmanned air vehicles

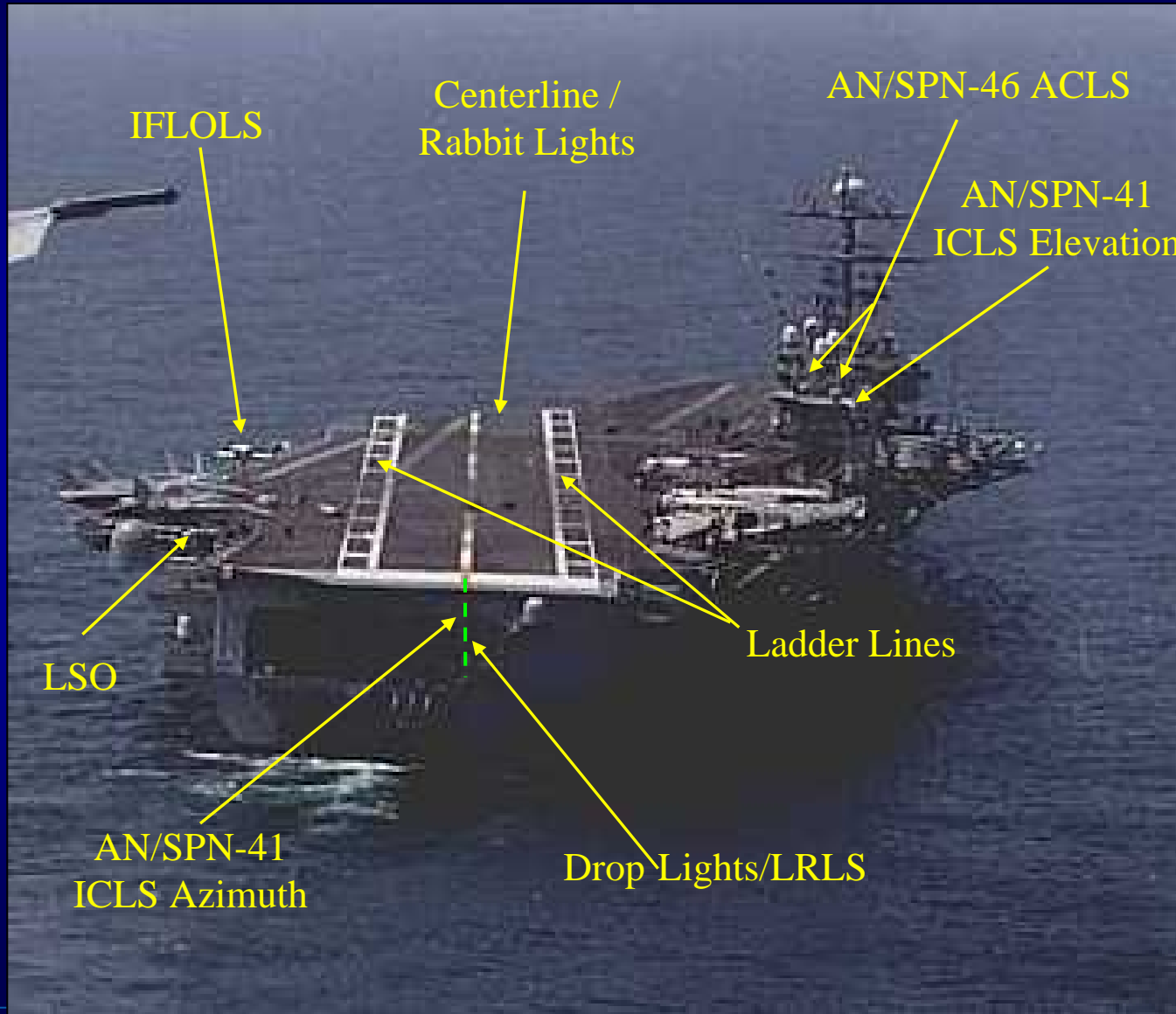
- **Primary areas of T&E expertise**

- Precision Approach and Landings Systems (PALS)
- Visual landing aids
- Aircraft landings aids
 - **Auto Throttle Systems**
 - **Auto Pilot Systems**
 - **Displays**





Aircraft Carrier Landing Aids



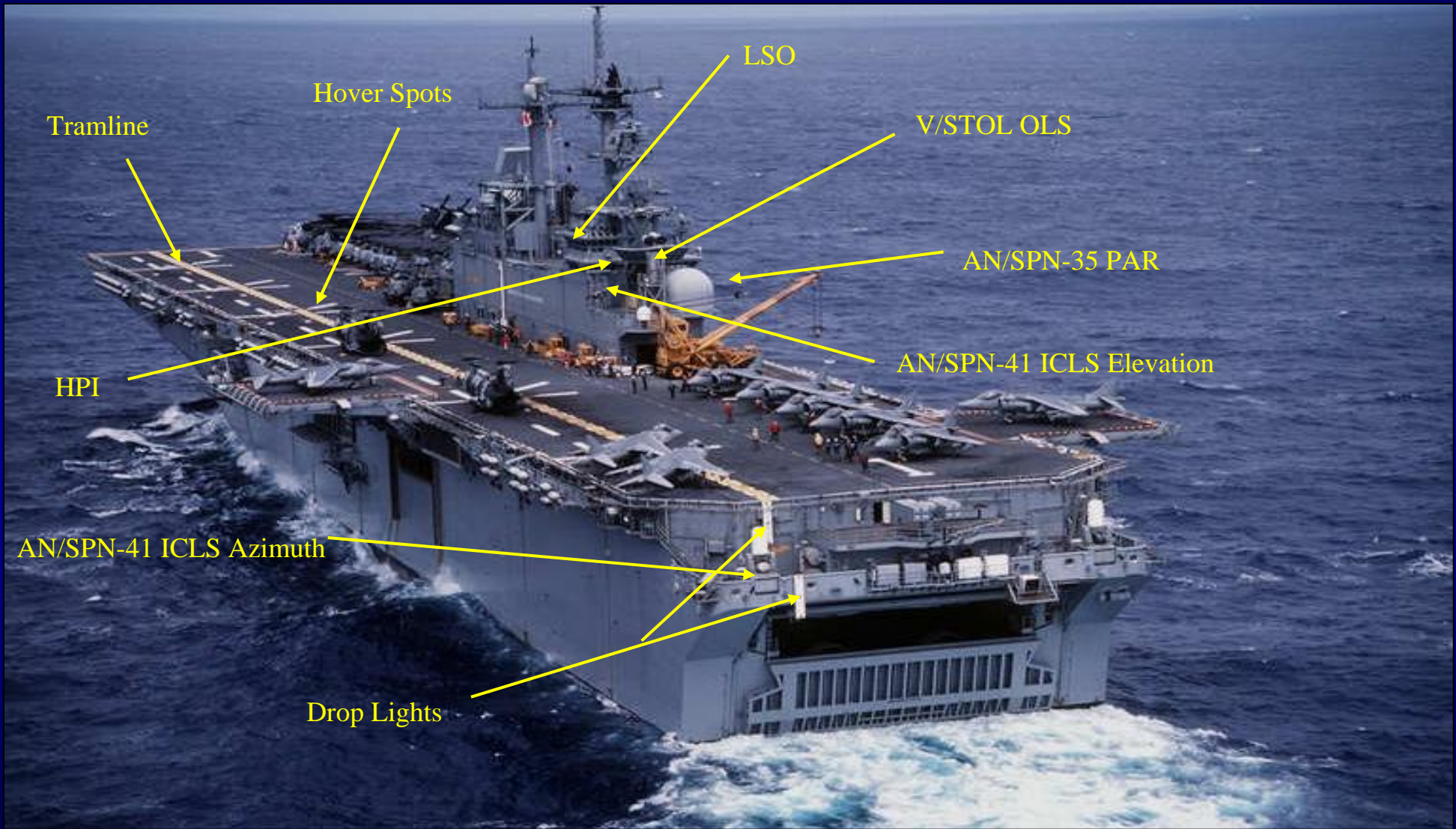


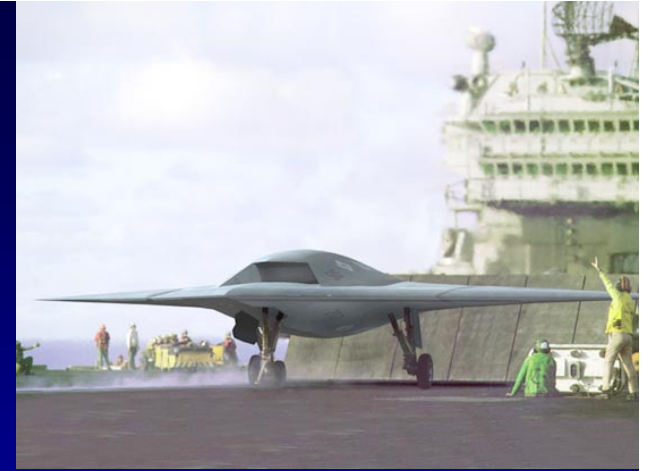
PALS Approach





Amphibious Assault Ship Landing Aids





Aviation Programs





Rotary Wing Aviation Programs

MV-22

UH-1Y and AH-1Z Upgrades

MH-60R/S

Presidential Helicopter Program

Heavy Lift Helicopter Program



V-22

- **Shore based and shipboard developmental test requirements are complete**
- **Further testing required**
 - Increase launch and recovery wind envelopes for all classes of ships
 - Software regression testing





UH-1Y / AH-1Z

- Major upgrades to the UH-1 Huey and AH-1 Cobra
 - New four bladed main rotor / Increased engine power
 - Increased gross weight
 - New cockpit
 - Survivability upgrades
 - Significant increase in commonality between UH-1 and AH-1



- Test program

- Shore based and shipboard developmental test requirements are complete, DI tests in 2005
- Further testing required
 - Increase launch and recovery wind envelopes for all classes of ships
 - Cockpit integration



MH-60R/S

- The MH-60R/S programs are upgrade programs that will provide capability improvements to U.S. Navy SH-60 series helicopters and introduce new capability
 - Mission areas for the MH-60R
 - Undersea Warfare, Anti-Surface Warfare, Area Surveillance and Combat Identification, Naval Surface Fire Support, Search and Rescue
 - Mission areas for the MH-60S
 - Vertical Replenishment, Amphibious Search and Rescue, Vertical Onboard Delivery, Airborne Mine Countermeasures, Combat Search and Rescue
- DI testing
 - MH-60R: Essentially complete
 - MH-60S: On-going





VH-71/CH-53K

- **VH-71 Presidential Helicopter will have shipboard operating capability**
 - DI testing planned in 2009
- **CH-53K Heavy Lift Helicopter**
 - Replaces the CH-53E, improved lift capability / R&M
 - DI testing in 2011/2012 timeframe





Fixed Wing Aviation Programs

F-18A-F Follow-On Test and Evaluation

EA-18G

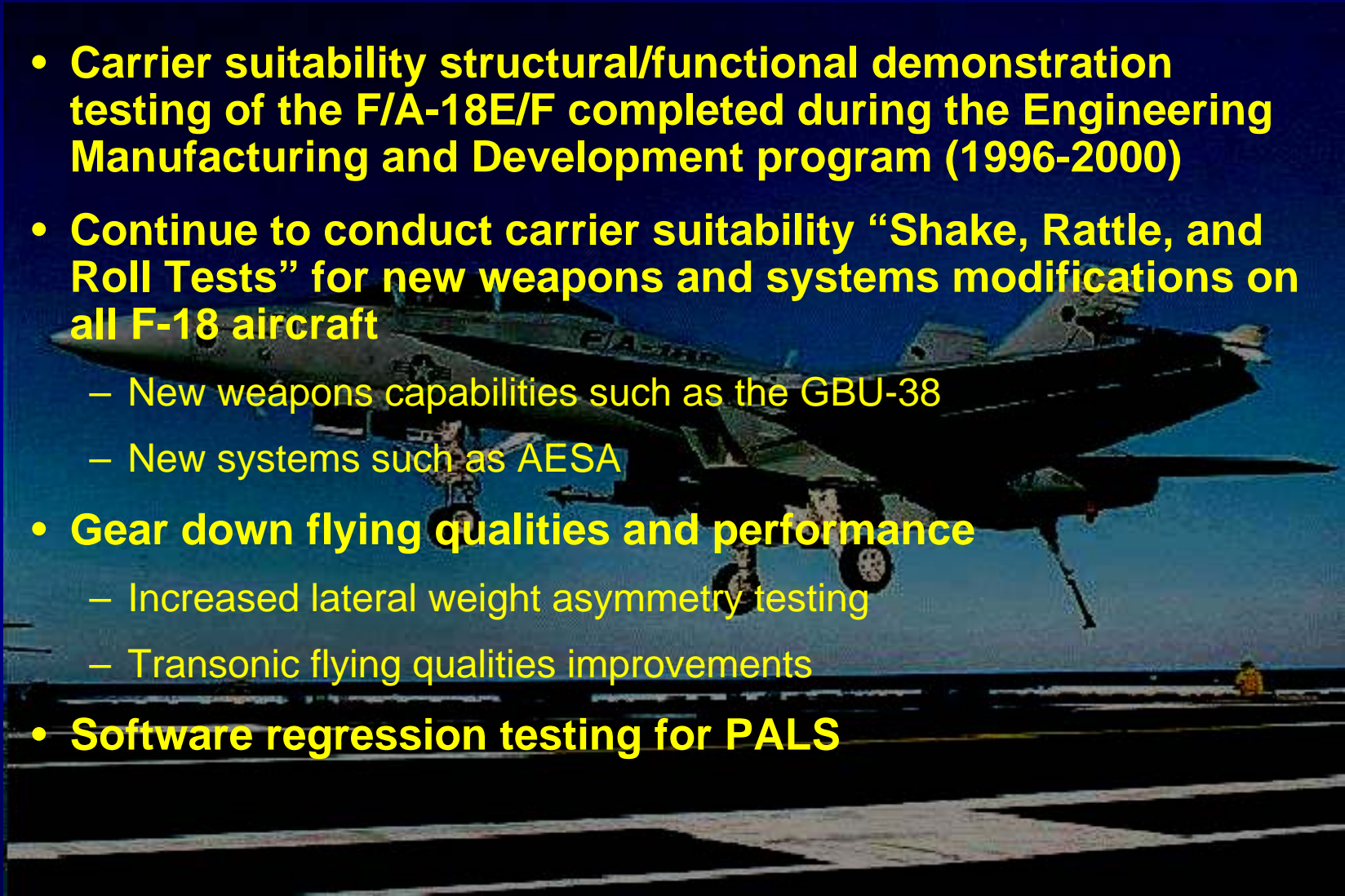
E-2/C-2 Programs

F-35B and F-35C



F/A-18A-F

- **Carrier suitability structural/functional demonstration testing of the F/A-18E/F completed during the Engineering Manufacturing and Development program (1996-2000)**
- **Continue to conduct carrier suitability “Shake, Rattle, and Roll Tests” for new weapons and systems modifications on all F-18 aircraft**
 - New weapons capabilities such as the GBU-38
 - New systems such as AESA
- **Gear down flying qualities and performance**
 - Increased lateral weight asymmetry testing
 - Transonic flying qualities improvements
- **Software regression testing for PALS**





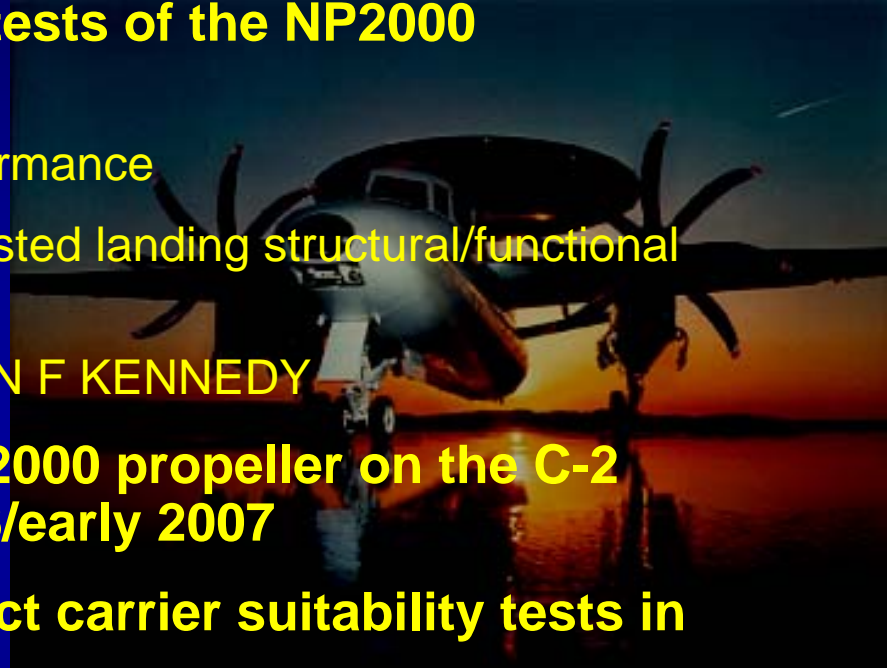
EA-18G

- EA-18G will replace the EA-6B
- Air vehicle testing underway with F/A-18E/F aircraft
- Carrier suitability test requirements
 - Flying qualities and performance
 - New external load configuration
 - Catapult launch and arrested landing structural demonstration of aircraft modifications and external pods
 - Includes increased gross weight for carrier landings
 - Also expanding lateral asymmetry capability for all F/A-18E/F/G aircraft
 - PALS testing



E-2 Hawkeye / C-2 Greyhound

- **Very successful carrier suitability tests of the NP2000 propeller on the E-2 Hawkeye**
 - Shore based flying qualities and performance
 - Shore based catapult launch and arrested landing structural/functional demonstration
 - Shipboard tests aboard the USS JOHN F KENNEDY
- **Plan to commence testing the NP-2000 propeller on the C-2 Greyhound to commence late 2006/early 2007**
- **E-2D Advanced Hawkeye to conduct carrier suitability tests in 2008**
 - Increased catapult launch and arrested landing gross weight
 - **Structural functional tests**
 - **Flying qualities and performance**
 - PALS





Joint Strike Fighter

- **Tests with F-35B STOVL and F-35C Carrier variants**

- F-35B testing scheduled to commence in 2008

- **First all-new STOVL tactical jet aircraft designed for U.S. operational use**

- **Ski jump tests**

- **First at-sea testing in 2010**

- F-35C testing scheduled to commence in 2009

- **Last of three variants to enter testing**

- **Least common of the three variants**

- **At-Sea testing in 2010**



Air Traffic Control and Landing Systems Programs

Aircraft Carrier and Amphibious Assault Ship PALS Certification

Joint Precision Approach Landing System (JPALS)

MV-22

UCARS



PALS Certification

- **SPN-46 Automatic Carrier Landing System (ACLS)**
 - All CV/CVN ships
 - Includes “hands-off” automatic landing
- **SPN-41 Instrument Control Landing System (ICLS)**
 - CV/CVN and LHA/LHD ships
 - Provides “needles” indication
- **AN/SPN-35 Precision Approach Radar**
 - LHA/LHD ships
 - Provides ship-based controller “talk down” approach capability to all aircraft





JPALS

- **Joint Precision Approach Landing System**

- JPALS will provide shore and shipboard precision approach systems

- Shore based system uses a Local Area Differential GPS (LDGPS) solution.
- Sea based system uses a relative solution (Shipboard Relative GPS (SRGPS)).

- Required for N-UCAS

- Will be implemented in all fixed and rotary wing aircraft

- ATC & landing during Emissions Control (EMCON)

- Air Traffic Management for N-UCAS/UAV's

GPS Satellite Signals

Sea-Based JPALS
(all aviation ships)

GPS-INS Navigation
Enroute

Shore Based
JPALS

Covert Ship
Data Link
200 NM

Data
Broadcast
30 NM



MV-22

- **Shore based developmental and certification test flights have been completed, or are in process on the following Uncoupled and Coupled Flight Director and Autopilot modes:**
 - Approach to hover
 - Coupled hover
 - Waypoint mode
 - Instrument Landing System
 - TACAN





UCARS/VTUAV

- **The Unmanned Common Automatic Recovery System is being used with the Fire Scout VTUAV for Launch and Recovery**



- UCARS will be incorporated in LCS for VTUAV Launch and Recovery
- Functions similarly to the AN/SPN-46 ACLS

An aerial photograph of a fleet of approximately ten large naval ships, likely frigates or destroyers, sailing in formation on a deep blue sea under a clear sky. The ships are arranged in a loose, staggered pattern, moving from the upper left towards the lower right. Each ship leaves a white wake behind it. The ships are white with dark hulls and various superstructures. The overall scene is a professional military or naval operation.

Ship Programs



LPD 17 Landing Platform Dock



- **Strategic for “Forward from the Sea”**
- **Designed to transport the latest Marine Corps hardware – called the Mobility Triad**
 - Advanced Amphibious Assault Vehicles (AAAV)
 - Landing Craft Air-Cushioned (LCAC)
 - MV-22 Osprey
- **LPD 17 testing commenced in 2006**
 - All Navy/Marine ship-capable helicopters (including V-22)
 - AV-8B Harrier tests in 2007





Littoral Combat Ship

- **Flagship for Naval transformation**

- Shift from blue water to littoral operations
- High speed capability / Long range
- Missionized modules for
 - **Mine warfare**
 - **Anti-submarine warfare**
 - **Anti-surface warfare**



Lockheed Design



General Dynamics Design

- Designed for manned and unmanned aircraft operations
 - **MH-60R/S**
 - **VTUAV**
- Each contractor to build two ships
 - **DI testing of first ship in 2008**



DDG 1000

- **Revolutionary Design**
 - Initial Fleet capability in 2013
 - Two helicopter landing spots
 - **MH-60R**
 - **UAV's**





USS George H. W. Bush CVN-77

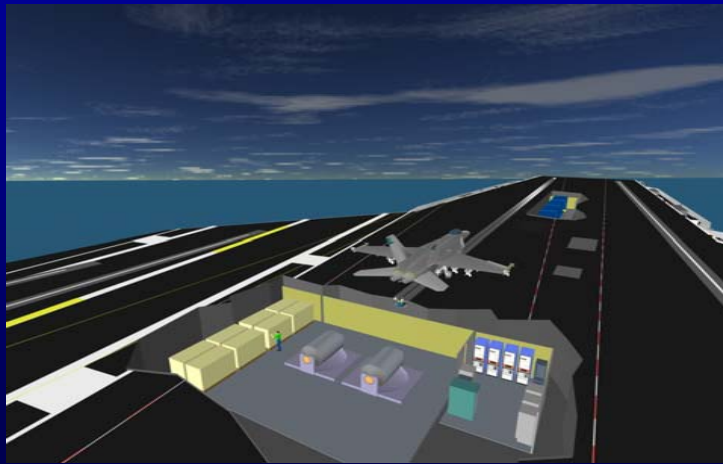
- **10'th and final Nimitz Class carrier**
- **Similar to USS Ronald Reagan, CVN-76**
 - Island shifted aft
 - Three arresting gear wires
- **Enters service in 2009**
- **Modernized island**
- **New radar tower**





CVN 21

- New design
- Optimized flight deck for air operations
- Decreased manpower
- Electromagnetic Aircraft Launch System (EMALS)
- Advanced Arresting Gear (AAG)





UAV and UCAS Programs

Small UAV's

RQ-8A/B Fire Scout

X-45 / X-47 N-UCAS



Small UAV's

- **Many different UAV's with many different launch and recovery concepts**

- Fixed Wing UAV's

- **Pneumatic and bungee powered launchers**
- **Net, vertical cable, and horizontal cable arrestment systems**

- Helicopters

- **Harpoon type system for launch and recovery**

- Types of control stations

- **Integrated / stand-alone**

- Vehicle control methods for launch and recovery

- **Manual**
- **Automatic**





Why We Test UAV's





RQ-8A/B Fire Scout

- **Vertical Takeoff Unmanned Air Vehicle for the Navy**
 - Design based on a Schweizer 330 commercial manned helicopter
 - RQ-8A missions include Reconnaissance, Surveillance, and Target Acquisition
 - RQ-8B to add increased payload and weapons capability
- **Autonomous Takeoff and Landing capability (ship and shore)**
- **Successful shipboard demo in Jan 2006 aboard the USS Nashville (LPD-13)**

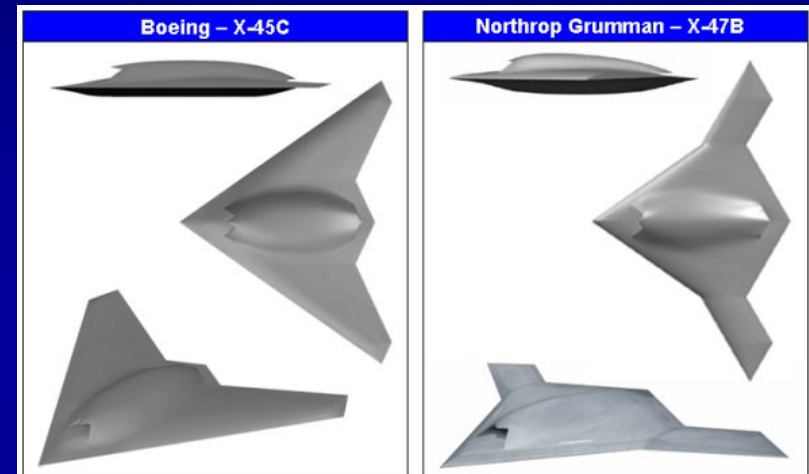




N-UCAS

- **Biggest challenge for ship suitability T&E**

- F/A-18 sized aircraft with weapons capability
- Long range / persistence
- Deployed on aircraft carriers
 - **Catapult launch and arrested landing capability**
- Autonomous launch and recovery
 - **Must be integrated into normal shipboard operations**
 - Deck operations
 - Integrated into the Carrier Air Traffic Control Center



- **Shore based and shipboard carrier demo in 2009**

Ship Suitability T&E Tools

Demonstrators

Modeling and Simulation





Demonstrators



Demonstrators – HSV / X-Craft



- Used to develop concept of operations for the Littoral Combat Ship
- DI tests conducted on both HSV-1 and HSV-2



- Littoral Surface Craft – Experimental (also known as the X-Craft) christened in February 2005 as USS Sea Fighter
 - DI tests conducted in December 2005



X-35 Concept Demonstrators

- This JSF “X” program was not a fly-off
- The demonstrators were used to
 - Reduce risk in critical areas
 - STOVL lift system design
 - Surface erosion
 - Manufacturing techniques
- Demonstrate modeling and simulation capability
 - Vehicle performance prediction

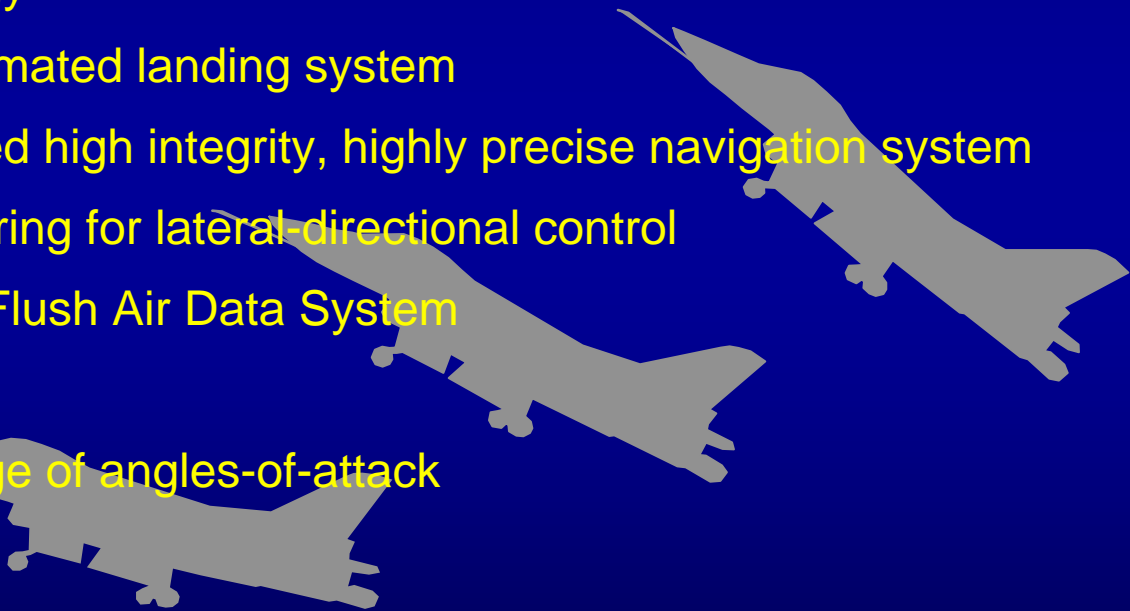




X-31 VECTOR

- **VECTOR - Vectoring ESTOL Control Tail-less Operation Research**

- Tests conducted using the X-31 to evaluate capability to fly approaches at very high angles-of-attack to demonstrate extremely short takeoff and landing technology
 - Requires fully automated landing system
 - Integrated advanced high integrity, highly precise navigation system
 - Use of thrust vectoring for lateral-directional control
- Evaluated advanced Flush Air Data System
 - Redundancy
 - Accuracy over range of angles-of-attack

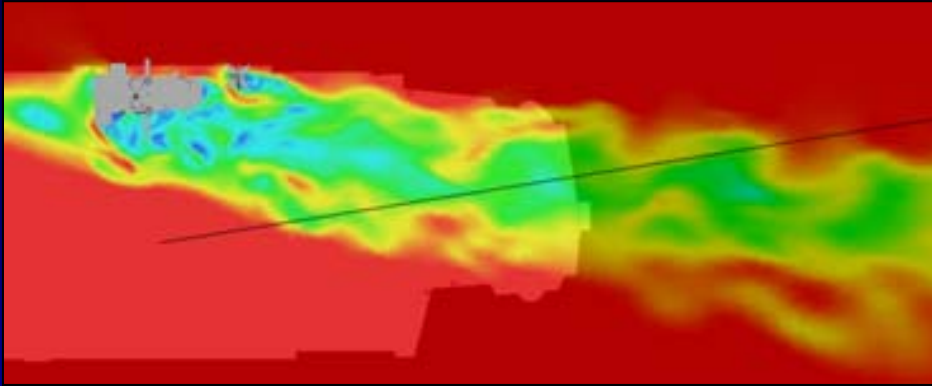




Demonstrators – Surrogate Testing

- **Often used surrogate vehicles to reduce the cost of testing and complete preliminary evaluations of new technologies**
 - Small twin engine commercial aircraft for PALS and JPALS testing
 - VAAC Harrier used for JSF STOVL
 - **Control law development and demonstration**
 - **Autoland development and demonstration**





Modeling and Simulation (M&S)

General

Wind Tunnel

CFD

Displays

Other Initiatives



M&S – General

- **Historical improvements**

- Catapult minimum endspeed predictions
- Approach airspeed evaluations
- Degraded flight control modes and emergency configurations

- **F-35 control law development**

- **PALS**

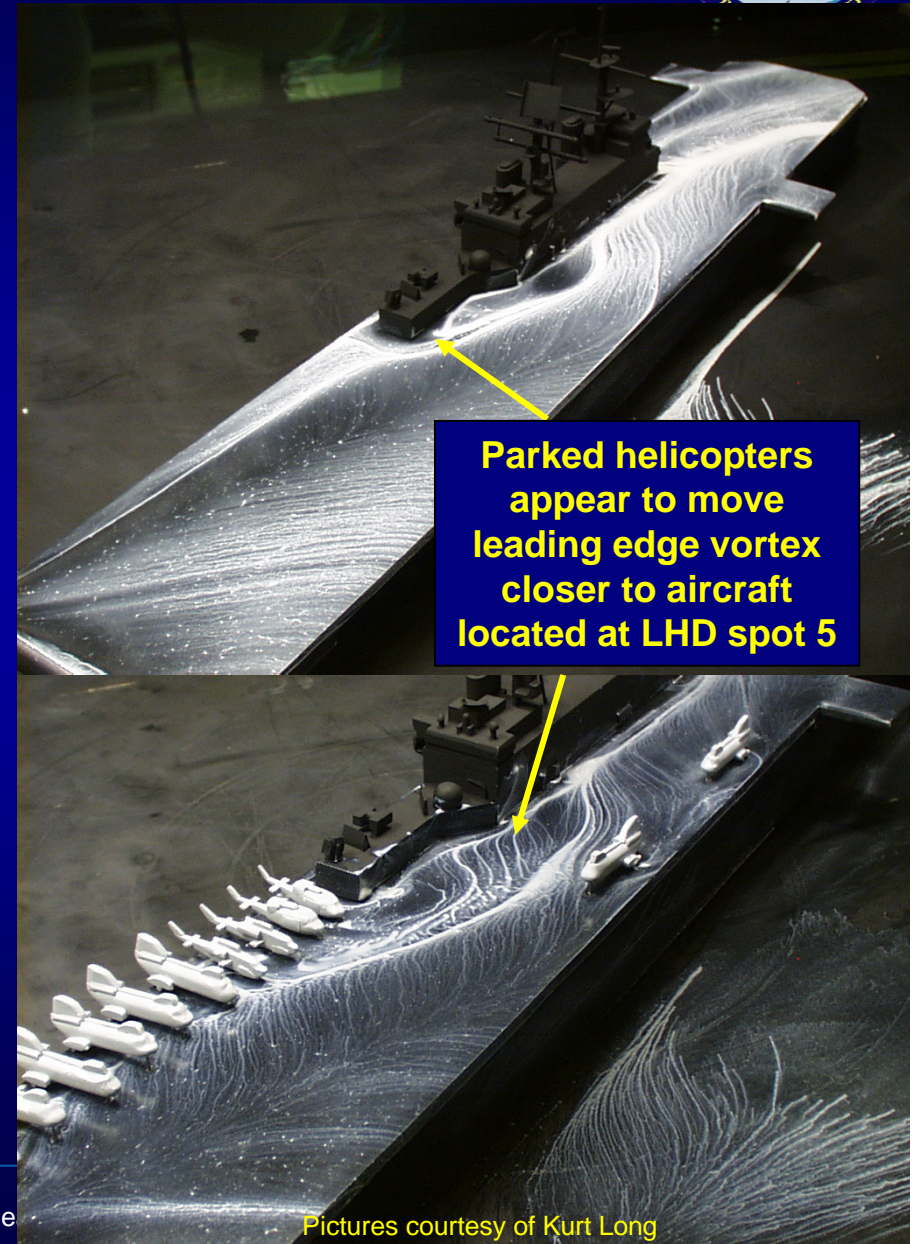
- Aircraft auto-pilot and auto-throttle control law development
- Ship/Shore based ACLS system control law development





M&S – Wind Tunnel

- **Measure ship's airwake**
 - Investigate effects of ship's topside configuration
 - Used to develop and confirm Computational Fluid Dynamics predictions
- **Ship's anemometers**
 - Determine optimum location
 - Develop source error corrections for Fleet use
- **Effects of aircraft parked on the flight deck**

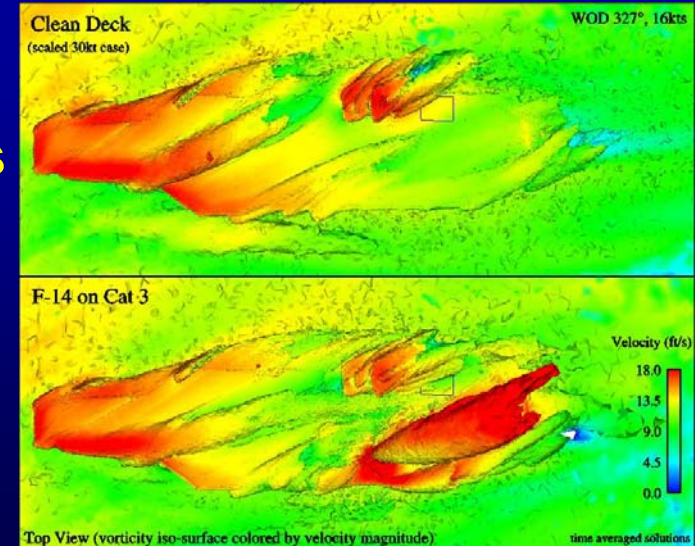
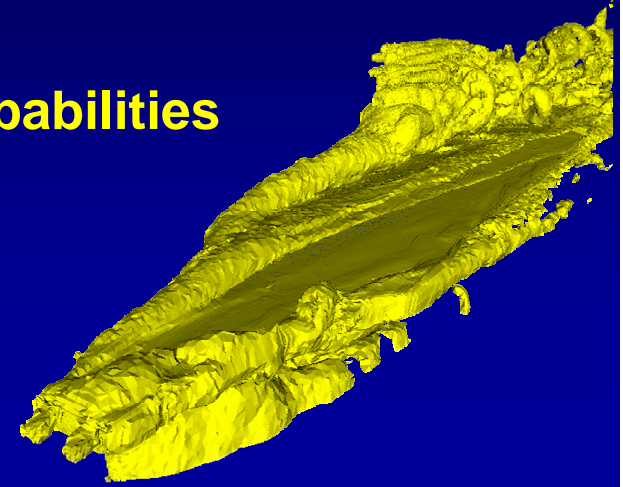




M&S – Computational Fluid Dynamics



- Utilizing NAVAIR Advanced Aero expertise and capabilities
- Ship's airwake predictions
 - Aerodynamic effect of deck and island geometry
 - Fixed wing aero performance and handling qualities investigations
 - Validation for CVN-21
- Predict aircraft interaction
 - JSF engine outwash
- Analysis of fixed wing / rotary wing interactions
 - F-14 engine exhaust velocities on helicopter operating in a new landing spot aft of the island

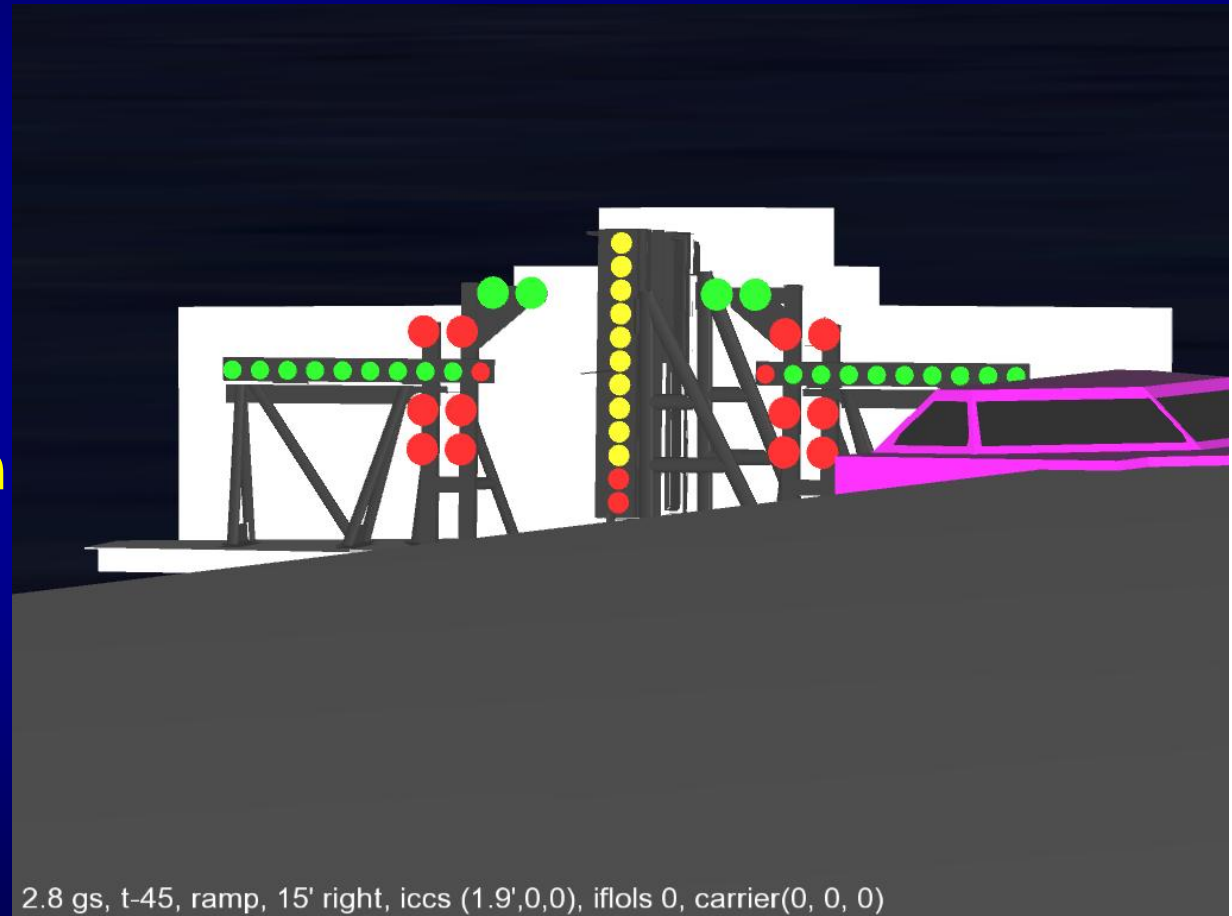


Pictures courtesy of Susan Polsky



M&S - Visual Displays

- Evaluation of new visual landing aids
- Evaluation of ship's topside layouts
- Utilize NAVAIR Human Factors expertise



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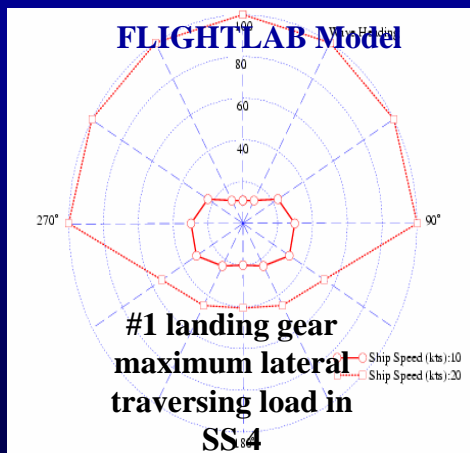


M&S – Other Initiatives

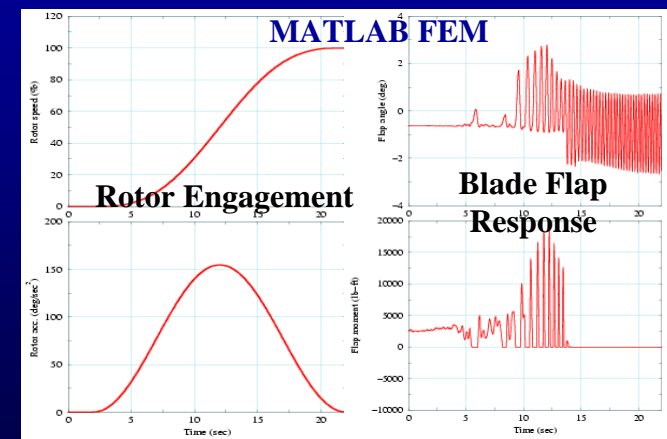


• In-Work Items

- Enhanced rotorcraft aerodynamics models that focus on dynamic stall, rotor tip design, high rate of descent and downwash
- Helicopter rotor engage/disengage model
- PC-based visual landing aid (VLA) test tool
- Helicopter deck traversing and securing analysis tool



Pictures courtesy of Dean Carico





Unique Challenges

UAV / UCAS

Data Collection and Analysis

Fleet/Program Response

Test Techniques



UAV/UCAS Challenges

- **Performance specifications**
- **Innovative Launch and Recovery techniques**
- **Myth of the expendable air vehicle**
- **Test unique procedures**
 - Test unique flight profiles
 - Replicating the Carrier Controlled Approach (CCA) environment
 - Shipboard testing



Data Collection and Analysis

- **Constraints during shipboard testing**
 - Real estate / situational awareness issues
 - Requirement for quick turnaround of data
- **JPALS data collection challenge**
- **F-35 data quantity challenge**
- **Data analysis tools in development**
 - Intelligent aircraft/ship data analysis options to help support future aircraft/ship testing and related database requirements
 - Analytic capability to support multi-aircraft/ship testing and related analysis





Response Challenges

- Quick response test requirements to provide immediate capability based on emerging Fleet requirements or technical issues
- Within last year, we have deployed teams to:
 - Carrier operating in WESTPAC (PALS support)
 - Carrier operating in Persian Gulf (PALS support)
 - Command and Control ship operating off of Korea (DI)
 - Scan Eagle emerging requirements on four ship types (DI)
- These “pop-up”, immediate support requirements stretch staffing requirements

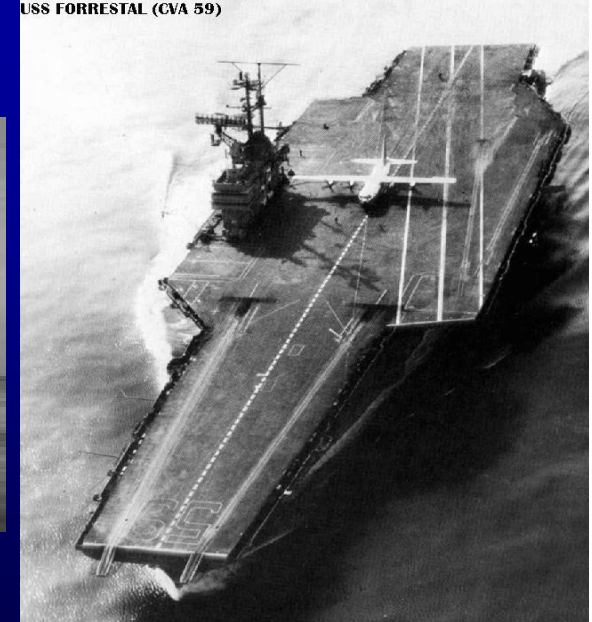


Test Techniques – Learning from the Past

- **C-130 deck launch / AV-8B STOVL / Conventional Ski Jump**
 - Reviewing tests conducted decades ago to glean information
 - Not all testing feasible in today's environment of Operational Risk Management



USS FORRESTAL (CVA 59)





Test Techniques – New Technology Areas



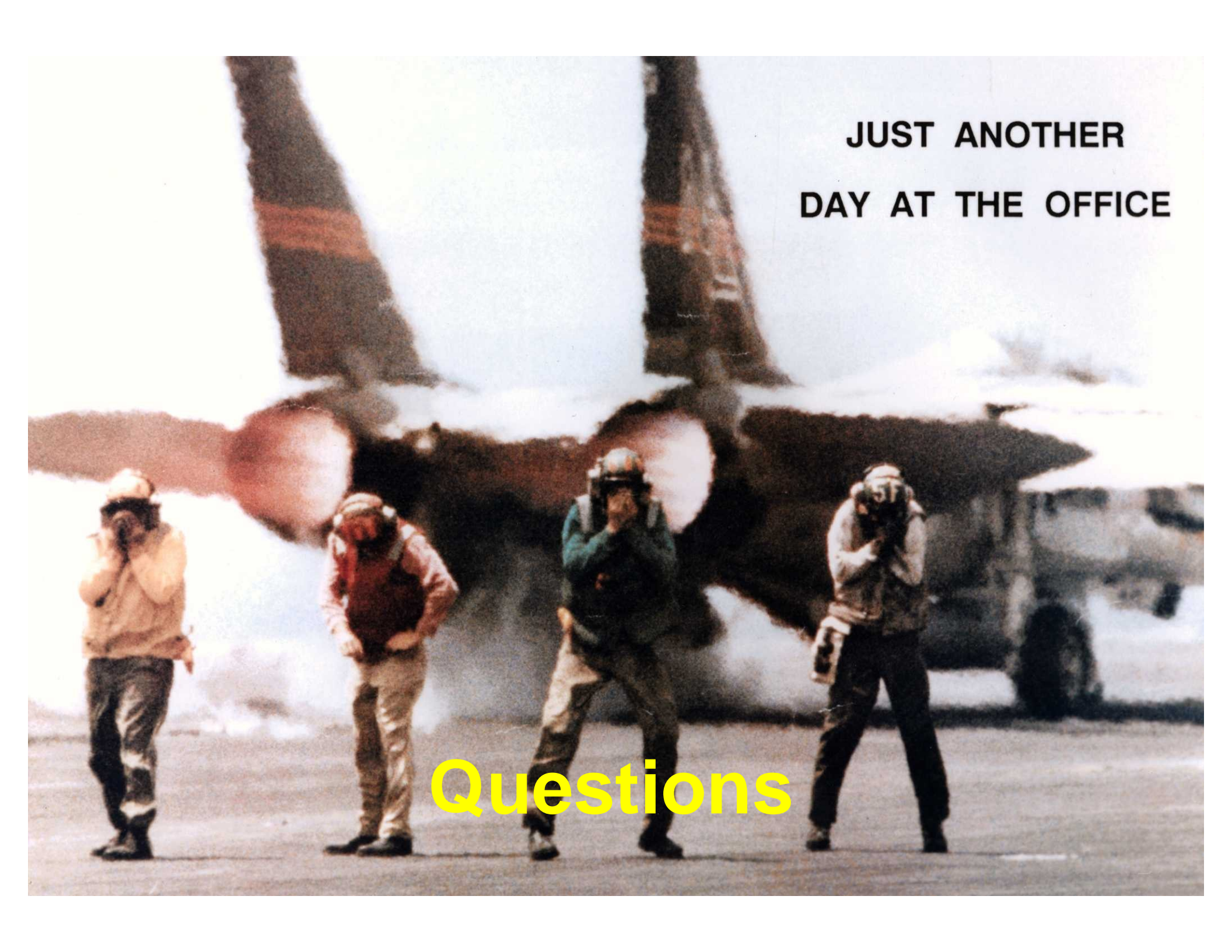
- **On-aircraft test aids**
 - Increased capability while testing on ships
 - Dial-a-Function
 - Net capable TM
- **Creating new techniques**
 - JPALS data collection
 - UAV test requirements and techniques
 - **N-UCAS**
 - **Small UAV's**





Summary

- Large number of aircraft and ship test programs facing the ship suitability T&E group
- Must be able to support these programs with less manpower
 - Test team versatility
 - Increased dependency on M&S
 - Better data analysis tools
- Must learn from past programs
 - C-130
 - AV-8B STOVL
 - Conventional Ski-Jump
- Develop new and innovative test techniques
 - JPALS
 - N-UCAS



**JUST ANOTHER
DAY AT THE OFFICE**

Questions



Video

