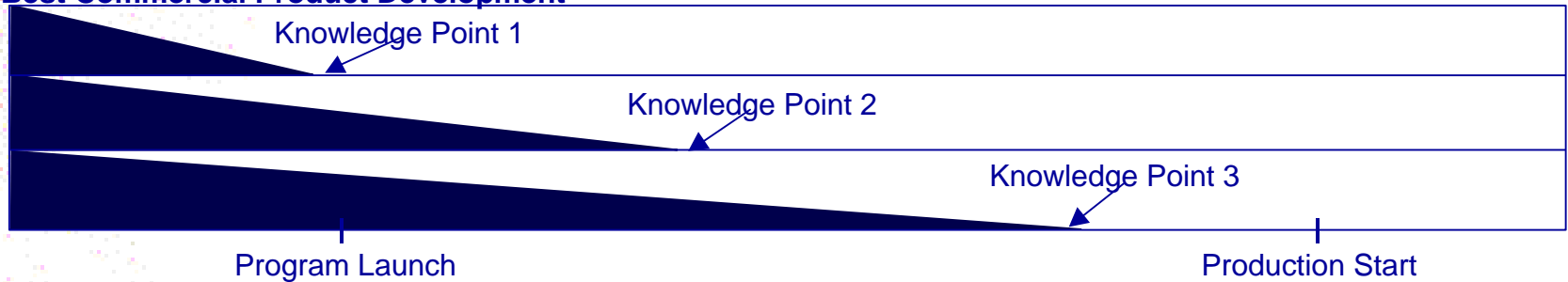


PRESENTATION TO THE V-22 BLUE RIBBON PANEL

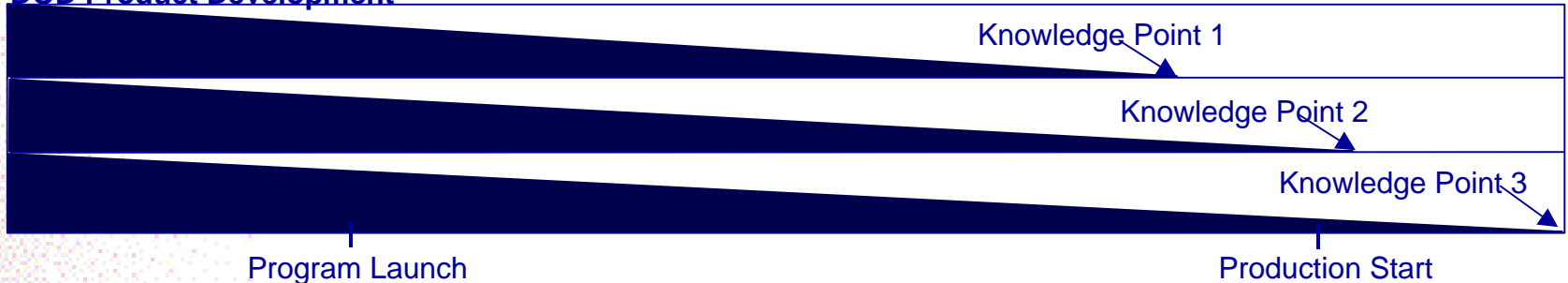
JANUARY 12, 2001

Knowledge at Key Junctures Is Critical to a Successful Transition to Production

Best Commercial Product Development



DOD Product Development



Unknowns
 Knowns

Knowledge Point 1: Knowledge that a match exists between technology and requirements.

Knowledge Point 2: Knowledge that the design will work as required.

Knowledge Point 3: Knowledge that the design can be produced within cost, schedule, and quality targets

Summary - Significant Risk With Proceeding With Full-Rate Production

- KNOWLEDGE OF V-22 DESIGN AND PERFORMANCE PARAMETERS FALLS SHORT OF WHAT SHOULD HAVE BEEN KNOWN BEFORE BEGINNING PRODUCTION
 - DEVELOPMENTAL FLIGHT TESTING WAS DELETED, DEFERRED OR SIMULATED
 - OPERATIONAL TEST WAIVERS AND LIMITATIONS REDUCED TESTING FOR OPERATIONAL REALISM
 - ASSESSMENT BASED ON REDUCED SYSTEM REQUIREMENTS
- MAJOR CONCERNS RAISED IN OPEVAL, JAG REPORT, OPEVAL DATABASE, DOT&E, OTHERS

Significant Risk With Proceeding With Full-Rate Production (cont.)

- RISKS OF MOVING FORWARD WITHOUT ADDITIONAL KNOWLEDGE
 - VALUE OF SYSTEM FOR MARINE CORPS OPERATIONS NOT YET ESTABLISHED
 - CONNECTION BETWEEN DEMONSTRATED PROBLEMS NOT KNOWN; UNKNOWN PROBLEMS NOT DISCOVERED
 - FPIF/CPIF CONTRACT EXPOSES GOVERNMENT TO RESPONSIBILITY TO FUND ANY DESIGN MODIFICATIONS - SOME, PERHAPS SIGNIFICANT, CHANGES ARE LIKELY
 - LONGER TERM RISK TO MODERNIZATION ACCOUNT AS COST INCREASES BEYOND ALREADY BUDGETED FUNDS ARE LIKELY
 - MARINE CORPS BUDGET IMPACTED BY MAINTAINABILITY SHORTFALLS

Current V-22 Effort

- Current analysis (began in September 2000) based on our review of program documents and interviews with officials responsible for managing and overseeing V-22 development
- We reviewed numerous program documents, such as
 - Test plans and requirements documents
 - Development test reports
 - Early/limited operational test reports
 - Development/operational transition reports
 - Operational test database
 - Navy and DOT&E reports of operational test results
 - Results of program oversight including deficiency reports
 - JAG and other V-22 crash (April 2000) investigation documents

Current V-22 Effort (cont.)

- We interviewed the following
 - V-22 Program Manager
 - V-22 Chief Engineer
 - V-22 ITT officials
 - Navy Warfare Requirements (N-8) officials
 - Navy Test and Evaluation (NO-91) officials
 - Navy Bureau of Inspections and Survey officials
 - V-22 Operational Test Director
 - Director Operational Test and Evaluation

Current V-22 Effort (cont.)

- Briefed our preliminary results to DOD and Navy officials responsible for executing and oversee the V-22 development effort in November 2000
 - V-22 Program Manager
 - Navy Operational Test Community (N912 and OPTEVFOR officials, and the V-22 Operational Test Director)
 - DOD's Director Operational Test and Evaluation
 - Secretary of the Navy (Research, Development & Acquisition) Deputy Assistant Secretary (Air Programs)

GAO FINDINGS - DEVELOPMENTAL FLIGHT TESTING WAS DELETED, DEFERRED OR SIMULATED

- Baseline development flight test program restructured numerous times to meet program cost and schedule pressures
 - Deleted significant testing that would have provided additional knowledge on V-22 flying qualities and susceptibility to Vortex Ring State
 - Deferment of “Height Velocity (HV) Diagram” tests, which identifies aircraft “no fly zones”, until after OPEVAL
- Increased use of simulators proposed to reduce need for manned flights
 - Accuracy of simulated flight tests questioned in Navy INSURV readiness for OPEVAL report, and OPTEVFOR’s V-22 OPEVAL report

GAO FINDINGS - OPERATIONAL TEST WAIVERS AND LIMITATIONS REDUCED TESTING FOR OPERATIONAL REALISM

- Prior to OPEVAL, program management requested and was granted numerous operational test waivers due to
 - failure to meet criteria,
 - inability to meet ORD threshold requirements, and
 - Part I deficiencies identified during development tests, including flight maneuver restrictions (max angle of bank and Gs) and prohibitions on flight in icing conditions
- INSURV approved the V-22 for OPEVAL contingent on resolution of Part I deficiencies
- DOT&E reported that several waivers created major or minor limitations to OPEVAL

GAO FINDINGS - OPERATIONAL TEST WAIVERS AND LIMITATIONS REDUCED TESTING FOR OPERATIONAL REALISM (cont.)

- Additional limitations, warnings and cautions were imposed on operations through flight clearance messages at various points during operational test
 - shipboard operations prohibited
 - rescue hoist and rescue hoist fast rope operations prohibited
 - operations within 25 NM of storm cloud formation prohibited
 - formation flight allowed only with 250 ft. separation

GAO FINDINGS - ASSESSMENT BASED ON REDUCED SYSTEM REQUIREMENTS

Critical Operational Issues (COI) eliminated from test master plan (TEMP) revised prior to OPEVAL

- revised 1999 TEMP reduced number of effectiveness COIs from 7 to 4
- amphibious operations, Marine Expeditionary Unit (Special Operations Capable), and joint interoperability eliminated from previous (1995) TEMP

GAO FINDINGS - ASSESSMENT BASED ON REDUCED SYSTEM REQUIREMENTS (cont.)

Performance Requirements changed in ORD prior to OPEVAL

- Performance requirements changed to match V-22 performance capabilities in two areas
 - land based short take-off distance (increased from 500 ft. to 3000 ft.)
 - on-board oxygen supply (reduced from 7 individual stations to 4)

GAO FINDINGS - MAJOR CONCERNS RAISED IN OPEVAL, JAG REPORT, OPEVAL DATABASE, DOT&E

Vortex Ring State Concerns

- JAG, OPEVAL and DOT&E reports raise significant concerns about implications of V-22 high rate of descent operations
 - susceptibility to high rate of descent and/or loss of controlled flight can occur at any time and consequences are exceedingly grave
 - V-22 appears to be less forgiving than conventional helicopters
 - additional testing is needed including exploration of formation flight
 - follow-on tests won't be completed until sometime in CY2001

GAO FINDINGS - MAJOR CONCERNS RAISED IN OPEVAL, JAG REPORT, OPEVAL DATABASE, DOT&E (cont.)

Rotor downwash concerns

- OPEVAL report cites some concern about downwash - V-22 operational test database lists numerous concerns about impact of rotor downwash
 - creates brownout and whiteout conditions
 - makes fast rope and rescue hoist operations hazardous
 - reduces effectiveness of combatants
 - forces sand, snow, other matter into interior of aircraft and into aircraft components
- DOT&E final report lists downwash as an area of concern
 - testing had demonstrated that some required capabilities can be achieved with great difficulty, some capabilities are unlikely to be achieved, and some planned capabilities have yet to be tested for downwash effects

GAO FINDINGS - MAJOR CONCERNS RAISED IN OPEVAL, JAG REPORT, OPEVAL DATABASE, DOT&E (cont.)

Cabin dimensions/environment concerns

- Cabin dimension considered too small to carry 24 combat Marines - 15-18 combat Marines may be the limit
- Cabin environment can not be adequately controlled in extreme temperature conditions

GAO FINDINGS - MAJOR CONCERNS RAISED IN OPEVAL, JAG REPORT, OPEVAL DATABASE, DOT&E (cont.)

Suitability concerns

- INSURV report - MV-22 fails to meet mean flight-hours between failure and built-in-test false alarm rate Critical Technical Parameters - low reliability of the MV-22 aircraft weapon system poses the most significant risk to OT-IIE (OPEVAL)
- OPEVAL report - weapon system certified as ready for operational test and evaluation was immature and exhibited significant production deficiencies which caused excessive unplanned maintenance actions
- DOT&E report - MV-22 demonstrated marginal mission reliability, excessive maintenance manpower and logistic support requirements, and inadequate availability - V-22 availability, maintainability, and reliability rates compared unfavorably with fleet CH-46 experience causing it to conduct fewer missions abort during a mission more often, and pose significant increased maintenance burden

GAO ASSESSMENT

- BEST PRACTICES ARE CLOSELY CORRELATED WITH SUCCESSFUL PROGRAM OUTCOMES
 - DESIGN AND PROCESS MATURITY BEFORE BEGINNING PRODUCTION
 - KNOWLEDGE GAINED IN V-22 PROGRAM FALLS SIGNIFICANTLY SHORT OF SUCCESSFUL PROGRAMS
 - PROCEEDING INTO PRODUCTION BEFORE ADDITIONAL KNOWLEDGE IS GAINED POSES RISKS FOR DOD OPERATIONS AND BUDGETS
-

RELATED GAO REPORTS

- GAO has significant and varied experience addressing the DOD acquisition process including system development and operational testing
 - October 1997 - GAO/NSIAD-98-13, NAVY AVIATION: V-22 Cost and Capability to Meet Requirements Are Yet To Be Determined
 - April 2000 - GAO/NSIAD-OO-78, DEFENSE ACQUISITIONS: Need to Revise Acquisition Strategy to Reduce Risk for Joint Air-to-Surface Standoff Missile
 - May 2000 - GAO/NSIAD-OO-158, DEFENSE ACQUISITIONS: F/A-18E/F Aircraft Does Not Meet All Criteria for Multiyear Procurement
 - May 2000 - GAO/NSIAD-00-74, JOINT STRIKE FIGHTER ACQUISITION: Development Schedule Should Be Changed to Reduce Risks
 - July 2000 - GAO/NSIAD-OO-182, DEFENSE ACQUISITIONS: Howitzer Program Experiencing Cost Increase and Schedule Delays
 - July 2000 - GAO/NSIAD-OO-199, BEST PRACTICES: A More Constructive Test Approach Is Key to Better Weapon System Outcomes
 - August 2000 - GAO/NSIAD-OO-178, DEFENSE ACQUISITIONS: Recent F-22 Production Cost Estimates Exceeded Congressional Limitations
 - Forthcoming - GAO-01-288, BEST PRACTICES: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes

PRESENTATION TO THE V-22 BLUE RIBBON PANEL

BRIEFING SUPPORT MATERIAL

JANUARY 12, 2001

Briefing Support Material - Developmental Flight Testing Was Deleted, Deferred Or Simulated (Page 8)

- Development flight test program started Feb. 1997 - Restructured in August 1997, and April and June 1998
- Restructuring due to aircraft modifications, pilot currency, added unknown test requirements, significant unplanned maintenance, vendor supply problems
- Concurrent testing, extension of maintenance intervals, extended flying used to achieve restructured goals, removal of baseline test requirements, and use of manned flight simulator
 - Deferred/deleted development tests - Flight Control System Development Flying Qualities Testing, which included tests for the investigation of “Vortex Ring State” was reduced from 103 test conditions to 49. This reduced the scope of testing required for cost and schedule recovery. Of the 49 test conditions only 33 were actually flown - 16 conditions not flown were at 0, 40, and 80 knots at high gross weights,
 - Simulated development tests - a) Simulation of aircraft autorotation used in lieu of aircraft tests - INSURV concerned that contractor simulation model does not have adequate data to model autorotation, b) OPEVAL reported that contractor simulator did not replicate loss of controlled flight resulting from HROD

Briefing Support Material - Operational Test Waivers and Limitations Reduced Testing for Operational Realism (Page 9)

- 21 operational test waivers requested
 - One waiver requested for failure to meet criteria - V-22 mean time between failure and false alarm rate
 - 11 waivers requested for failure to meet requirements due to Part I deficiencies
 - inadequate cargo handling system
 - exterior lighting for NVG formation flight inadequate
 - external loads interferes with radar altimeter
 - lower cabin door operation in hover
 - autorotation descent cannot be maintained while attempting engine air start, etc.
 - 9 waivers requested due to inability to meet ORD thresholds
 - not cleared to operate in icing conditions
 - not cleared for air combat maneuvering
 - not cleared for aerial refueling
 - unable to fastrope out of cabin door, etc.

Briefing Support Material - Operational Test Waivers and Limitations Reduced Testing for Operational Realism (Page 9)

- Navy Board of Inspection and Survey recommended that the MV-22 proceed to OPEVAL contingent upon CNO approval of a number of Part I deficiency resolutions. These included deficiencies with published “Yellow Sheet Reports” and others that were unpublished (draft)
 - Part **I - 3 open (failure of proprotor lightning bond straps, excessive lightning currents on internal fuel lines, and later instability during shipboard vertical landings)
 - Part *I - 11 open (low reliability of MV-22 aircraft, excessive lateral-directional trim requirements during simulated in-flight refueling at 60 degree nacelle, single mission computer drop outs, exterior lighting for night vision goggles formation flight inadequate, etc.)
 - Part I - 26 open (low reliability of the multifunction display, high false alarm rate of BIT, unacceptable single mission computer drop outs, no indication of longitudinal maneuvering capability to the pilot, etc.)

Briefing Support Material - Operational Test Waivers and Limitations Reduced Testing for Operational Realism (Page 9)

- Deficiencies considered by INSURV to have greatest impact on operational tests were
 - Low reliability of the MV-22B aircraft weapon system
 - Lower cabin door operations in hover
 - Air data system faults during conversion mode aerial refueling operations
 - Excessive lightning currents on internal fuel lines
 - Autorotation survivability
 - Inadequate cargo handling system
 - Inadequate cockpit/cabin nuclear, biological, and chemical overpressure protection
- DOT&E report states that several waivers created major or minor limitations to OPEVAL
 - not cleared for air combat maneuvering
 - max short take-off (shipboard) weight lower than mission profile specific wt
 - not cleared for KC-135 tanker refueling
 - unable to fastrope out of cabin door

Briefing Support Material - Operational Test Waivers and Limitations Reduced Testing for Operational Realism (Page 10)

- Numerous limitations were imposed at various points in time during operational tests
 - flight envelope limitations - shipboard ops prohibited, short takeoff and landing limits, control inputs limits, max takeoff gross weight limits, max angle of bank limits, max G limits
 - flight control limitations - swashplate actuator fault advisory restricting airspeed
 - cargo system limitations - ramp limits, parachute OPS prohibited, rescue hoist OPS prohibited, external cargo OPS prohibited
 - environmental limitations - flight/ground OPS prohibited within 25nm of cumulonimbus clouds
 - fuel system limitations - hover in-flight-refueling prohibited, refueling from KC-10 prohibited
 - formation flight limitations - wingman shall avoid and not cross lead aircraft wake during formation flights, 250 ft. lateral and 50 step-up separation shall be maintained

Briefing Support Material - Vortex Ring State (Page 13)

JAG Report - Opinion Section Quotes

- After reviewing the evidence collected it was concerning to see how “easy” it was for the recipe of uncontrolled flight to be concocted.
- Aircraft performance envelopes are developed, and procedures and guidance published to prevent pilots from putting an aircraft in a situation that would exceed safe parameters. The MV-22 performance envelope may be one that fleet pilots can operate within, but given the rigors of combat, real world operations, and realistic training for both, the consequences of exceeding this particular envelope appears to be excessively grave.
- In traditional rotorcraft, power settling would cause uncommanded rates of descent and, depending on altitude, may result in a hard landing or quite possibly a controlled crash. In all likelihood, however, such an event would result in the aircraft hitting the ground in an upright attitude. In this respect, with regard to Vortex Ring State and/or Blade Stall, the MV-22 appears to be less forgiving than conventional helicopters. A V-22 ----- is capable of have one rotor impacted by the effects of Vortex Ring State and/or Blade Stall and the other not, resulting in an asymmetrical condition. We believe that this was the case of the mishap. The end result was a departure from controlled flight instead of a hard landing or controlled crash -----.
- The fact that the causes of these two incidents (referring to two recorded uncontrolled formation flight incidents during OPEVAL) are not known, coupled with limited development formation testing (4 flights for 11.7 hours); make it difficult to completely exclude turbulence or downwash as potential contributors to the mishap.

Briefing Support Material -Vortex Ring State (cont.) (Page 13)

JAG Report - Recommendation Section Quotes

- All V-22 operators should become acutely familiar with the potential consequences of high rates-of-descent combined with slow airspeeds that are present with tilt-rotor design ----- . The fact that this aircraft found itself in a Vortex Ring State condition with no apparent warning to the aircrew, but also departed controlled flight is particularly concerning. Until further testing is conducted on the Vortex Ring State phenomenon, safe flight will require strict adherence to procedures and limitations.
- PMA-275, PMA-205, and the contractor expedite incorporation of Vortex Ring State and Blade Stall warnings and procedures into the MV-22 NATOPS. The preliminary NATOPS manual and V-22 ground school syllabus provides insufficient guidance/warning as to high rate of descent/slow airspeed conditions and the potential consequences.
- NAVAIR continue to explore the aerodynamic effects of formation flight with the MV-22. The MV-22 will be operationally employed in a similar fashion to existing fleet aircraft. Multi-ship formations will be the norm as the aircraft executes its various missions. Questions still remain concerning potential aerodynamic influences, such as wake turbulence on wingman during formation flight.

Briefing Support Material -Vortex Ring State (cont.) (Page 13)

OPTEVFOR V-22 OPEVAL Report Quotes

- **Executive Summary** - The Naval Air Training and Operating Procedures Standardization (NATOPS) manual lacked adequate content, accuracy, and clarity. Additionally, because of incomplete developmental testing in the high rate of descent (HROD) regime, there was insufficient explanatory or emphatic text to warn pilots of the hazards of operating in this area. The flight simulator did not replicate this loss of controlled flight regime.
- The V-22 has the potential to enter high rates of descent at high nacelle angles with low airspeed. This condition occurs very rapidly with little to no warning to the pilots. In simulation at 95 degrees nacelle, 39 KCAS, and 0 feet per minute rate of descent (ROD), pulling the thrust control lever (TCL) full aft caused an immediate descent exceeding the 800 feet per minute NATOPS WARNING. If forward TCL is applied at this point, an uncontrolled flight condition is possible. Within 3 seconds, the simulator exhibited in excess of 3,000 fpm ROD.
- **Additional Recommendation** - Continue developmental testing to investigate HROD/loss of controlled flight phenomena and determine safe flight envelope for these conditions. Consider providing cockpit warning of this condition to the pilots to preclude entry into unsafe flight regimes.
- **Section 4 Test and Results** -The V-22 technical documentation did not support the operation and maintenance of the V-22. The NATOPS was plagued with inaccuracies that degraded flight operations and still contained FSD and EMD aircraft data not pertinent to production aircraft. Performance charts furnished by the developer to support OPEVAL were also inaccurate when compared to actual flight conditions and the CMS. Additionally, because of incomplete developmental testing in the HROD regime, there was insufficient explanatory or emphatic text to warn pilots of the hazard of operating in this condition.

Briefing Support Material -Vortex Ring State (cont.) (Page 13)

DOT&E Operational Test and Evaluation Report Quotes

- **Executive Summary** - Vortex Ring State can occur in all rotary-wing aircraft under similar conditions of low airspeed and high sink rate. No mechanical or electrical failures in the aircraft were found to contribute to the mishap. In the tiltrotor V-22, the onset of VRS can occur in the proprotor on one side without the other side losing lift. In such a case, the aircraft tends to roll sharply into the side that first loses lift, resulting in large, unexpected bank angles, followed immediately by rapid dropping of the nose of the aircraft and a steep dive. At low altitudes, there may be no opportunity for recovery.
- While the possible existence of VRS in the V-22 was known when flight limits for OPEVAL were established, the unusual attitude following entry into VRS was not expected.
- Testing to date suggests that should a pilot inadvertently exceed published limitations, there may be no easily recognizable warning that the aircraft is nearing the danger zone - and some flight control inputs; e.g., a roll or yaw command, may trigger an asymmetric thrust condition. Such a situation can easily be envisioned in flight conditions that place a high workload demand on the pilots; e.g., night or low visibility, system malfunctions, hostile fire, etc., should a breakdown of crew coordination or loss of situational awareness occur. Thus, the first indication the pilot may receive that he has encountered this difficulty is when the aircraft initiates an uncommanded, uncontrollable roll. High rate-of-descent (HROD) testing continues to define the VRS phenomenon.

Briefing Support Material -Vortex Ring State (cont.) (Page 13)

DOT&E Operational Test and Evaluation Report Quotes

- **Executive Summary** - I believe that ongoing development testing should continue to explore the ability to detect proximity to the danger area in the flight envelope, with the objective of providing meaningful warning to the pilot, or control limitations, to avoid entry into this danger area and loss of control.
- Follow-on developmental and operational tests should involve multiple MV-22s, at heavy weights, in close time and space proximity as might be anticipated in the conduct of a combat assault mission. Such operational test would increase confidence that appropriate tactics exist to enable the MV-22s to deliver assault forces to a small area in a short time while avoiding undue exposure to enemy threats-without subjecting the aircraft to potential loss of control situations.
- **Operational Effectiveness Areas of Concern** - As noted previously, I fully endorse ongoing testing activities and recommend research efforts to better understand the Vortex Ring state phenomenon and the potential danger posed to the safe operation of the MV-22.
- A second, related concern involves the effects of maneuvering limitations imposed to avoid the vortex ring state danger area. Despite the OPEVAL finding that the restrictions had no operational impact, I am concerned that this constraint imposed to avoid loss of control may limit the maneuver capability and hence the effectiveness of the MV-22 in some operational scenarios. Ongoing developmental flight testing is intended to more accurately define the danger zone beyond the NATOPS flight envelope.

Briefing Support Material -Vortex Ring State (cont.) (Page 13)

DOT&E Operational Test and Evaluation Report Quotes

- A second phase of testing planned by Naval Air Systems Command to fully explore the potential aerodynamic interactions between MV-22 aircraft in proximity to each other. Until the final operational constraints upon descent rates and aircraft separation are established based upon ongoing developmental testing, and the appropriate tactics are confirmed in operational testing, the potential impact on the effectiveness of the MV-22 in performing some combat assault missions must be viewed with some reservations.
- Test Adequacy quotes - Examine thoroughly the circumstances in which the V-22 may depart from controlled flight in low-air-speed, high rates of descent. Investigate the potential for airflow interactions between nearby V-22s to initiate or aggravate vortex ring state.
- Demonstrate the end-to-end conduct scenarios involving multiple MV-22s making repeated back-to-back flights in close proximity in time and space to each other and other aircraft needed for the operations - as might be expected during the conduct of assault operations. (separation distance concern)
- Confirm the shipboard compatibility of multiple MV-22s operating simultaneously as would be needed in the conduct of substantive amphibious assault. (separation distance concern)

Briefing Support Material -Suitability Concerns (Page 16)

JAG Report - Opinion Section Quotes

- The maintenance/removal rates of the washplate actuators is concerning. The MOTT replaced 17 actuators during the OPEVAL period. Given their critical role in the aircraft's drive system, reliability of these actuators is imperative.
- The frequency of servicing/maintenance requirements, for aircraft hydraulic systems is concerning. Many maintenance man-hours have been spent maintaining and servicing the various aircraft hydraulic systems.