V-22 OSPREY

Navy ACAT IC Program		Prime Contractor
Total Number of Systems:	459	Bell-Boeing Joint Venture
Total Program Cost (TY$):	$41.157MM	
Average Unit Cost (TY$):	$89.7M	
Full-rate production:	2QFY01	

SYSTEM DESCRIPTION & CONTRIBUTION TO JOINT VISION 2020

The V-22 Osprey is a tilt-rotor vertical/short takeoff and landing (VSTOL), multi-mission aircraft developed to fill multi-Service combat operational requirements. The MV-22 will replace the current Marine Corps assault helicopters in the medium lift category (CH-46E and CH-53D), contributing to the ***dominant maneuver*** of the Marine landing force, as well as supporting ***focused logistics*** in the days following commencement of an amphibious operation. The Air Force requires the CV-22 to provide a long-range VTOL insertion and extraction capability and to supplement the Special Operations Forces (SOF) MC-130 aircraft in ***precision engagement***. The tilt-rotor design combines the vertical flight capabilities of a helicopter with the speed and range of a turboprop airplane and permits aerial refueling and worldwide self-deployment.

Two 6150 shaft horsepower turboshaft engines drive two 38-ft diameter, 3-bladed proprotors. The proprotors are connected to each other by interconnect shafting which maintains proprotor synchronization and provides single engine power to both proprotors in the event of engine failure. The engines and flight controls are controlled by a triply redundant digital fly-by-wire system.

The airframe is constructed primarily of graphite-reinforced epoxy composite material. The composite structure is intended to provide improved strength to weight ratio, corrosion resistance, and damage tolerance compared to typical metal construction. Battle damage tolerance is built into the aircraft by means of composite construction and redundant/separated flight control, electric and hydraulic systems. An integrated electronic warfare defensive suite including a radar warning receiver, a missile warning set, and a countermeasures dispensing system will be installed.

BACKGROUND INFORMATION

The V-22 is being developed to meet the provisions of the 19 May 99 Joint Multi-Mission Vertical Lift Aircraft (JMVX) Operational Requirements Document (JORD) for an advanced vertical lift aircraft. The JORD calls for an aircraft that will provide the Marine Corps and Air Force with the capability to conduct assault support and long-range, high-speed missions requiring vertical takeoff and landing capabilities.

During Full Scale Development (FSD) from 1986 to 1992, the V-22 T&E program principally concentrated on engineering and integration testing performed by the contractor. Three periods of formal development testing by Naval Air Warfare Center-Aircraft Division, Patuxent River, MD, plus OTA participation in integrated test team activities at Patuxent River, provided early insight into the development effort. After transition to EMD in 1992, an integrated contractor/government test team conducted all tests until OT-IIA in 1994. Starting with OT-IIA in 1994, a total of five periods of OT&E have been conducted.

The first three periods of OT&E used test aircraft from the earlier FSD program, with only limited flight time available, and extensive restrictions on allowable flight maneuvers. The main thrust of these OT&E periods was ground tests and simulation. OT-IID in 1998 was conducted using EMD aircraft numbers 9 and 10, the final two aircraft delivered under the EMD program. OT-IID consisted of 142.6 flight hours conducting operationally realistic missions at four locations: NAS Patuxent River, MD; New River MCAS, NC; Camp Dawson AAF, WV; and Eglin AFB, FL. At the conclusion of OT-IID, the MV-22 was found to be potentially operationally effective and potentially operationally suitable, although unrealistic maintenance procedures and contractor involvement skewed the reliability and maintainability data.

The ballistic design requirements specify “not-to-exceed” vulnerable areas for the following threats: 7.62mm API, 12.7mm API, 14.5mm API, and 23mm API. Hits could occur at either hover condition or during a 2-g maneuver. Following a hit, the aircraft must be able to complete a 30-minute flight and land vertically.

A waiver request from full-up, system-level Live Fire testing for the V-22 was supported by DOT&E and certified by the Secretary of Defense on April 25, 1997. An alternative LFT&E plan, approved by DOT&E prior to submittal of the waiver request, included a comprehensive series of ballistic tests of critical components, major assemblies, and aircraft structures. The V-22 alternative LFT&E plan was a balanced approach, which started early in the design process and utilized trade-studies, analytical and prediction tools, and realistic Live Fire testing. Live Fire testing was viewed as an integral part of the design process, not merely as a method of design verification. With this approach, problems could be identified early, allowing timely fixes that could be retested later in the program. The alternative LFT&E plan recognized that modeling and simulation alone is not sufficient to predict the vulnerability of a component or to identify potential design changes. A continuous process of design refinements has been an integral part of the system engineering effort since the start of Live Fire testing, and several design changes have been made based on the test results.

The V-22 Live Fire test program consisted of 582 shots over 16 years. Ballistic testing of the V-22 design began in 1984. From 1984-1990, a total of 51 ballistic test firings were conducted against pre-FSD components and subsystems. An additional 87 test firings against the FSD design were completed from 1994-2000. The EMD demonstration test series consisted on 444 test firings from 1996-2000 to demonstrate the final production aircraft design.

TEST & EVALUATION ACTIVITY

OT-IIE (OPEVAL) of the MV-22, began on November 2, 1999, and finished on July 21, 2000, accomplishing 804 flight hours in 522 sorties. OPEVAL was conducted with five MV-22 LRIP aircraft, aircraft numbers 11 through 15, aboard four Navy ships and at nine locations ashore.

The last remaining V-22 Live Fire test series were conducted in FY00. The following ballistic test series were completed: pylon conversion spindle, swashplate actuator, proprotor grip, proprotor yoke, aircraft structure, sponson hardening, aft sponson fire, empennage attachment hardware, and wing attachment hardware. The last four test series were accomplished by firing at a production-representative EMD aircraft (the EMD static test article).

DOT&E completed our evaluation of test adequacy, operational effectiveness, suitability, and survivability and submitted the required report to the Secretary of Defense and congressional defense committees in time to support the Milestone III decision by the Navy in November 2000.

DOT&E oversight of FOT&E will continue to verify correction of deficiencies and to ensure that deferred OT&E events are finished. Since additional design changes and improvements are currently being considered, our LFT&E oversight activities on the V-22 will continue as well. These changes include the addition of a self-defense weapon and addition fire suppression protection in the sponsons.

TEST & EVALUATION ASSESSMENT

Testing was adequate to determine the MV-22's operational effectiveness, operational suitability, and survivability. However, additional testing is needed to verify correction of deficiencies, the effectiveness and suitability of waived items, and to investigate the vortex ring state. The MV-22 is operationally effective but not operationally suitable. Results from OT-IIE (OPEVAL) indicate that the V-22 will provide major range, speed, and payload improvements to meet Marine Corps and Special Operations Forces (SOF) requirements. The V-22 offers significant maneuverability and handling advantages as compared to conventional helicopters; e.g., rapid deceleration upon arrival at a landing zone and rapid acceleration during departure. When tactics are fully developed, these capabilities should provide substantive mission accomplishment and survivability advantages. In addition, OPEVAL results indicated that with modified operational procedures, at least some required tasks could be performed despite the downwash experienced in the rotary mode, which had been an issue of concern in previous OT&E. The MV-22 meets all the key performance parameters specified in the Joint Operational Requirements Document.

Operational testing of the MV-22 did not demonstrate that the MV-22 as configured and tested during OPEVAL is operationally suitable. The MV-22 demonstrated marginal mission reliability, excessive maintenance manpower and logistic support requirements and inadequate availability, interoperability, human factors, documentation, and diagnostics capabilities. In the latter half of OPEVAL, the trends on some key measures of suitability were positive, suggesting that the aircraft has the potential to eventually meet its suitability requirements. Nonetheless, taken as a whole or considering only its improved suitability data from the second half of OPEVAL, the MV-22 failed to meet several important JORD established thresholds. Moreover, the demonstrated results for MV-22 mission reliability, maintainability, and availability were less favorable than the same measures from the fielded CH-46 fleet. The OPEVAL results also failed to confirm the reliability and diagnostic improvements postulated before the test.

Operational testing has shown that the MV-22, as configured and tested, did not achieve the established suitability thresholds for:

- Mean Flight Hours Between Aborts
- Mean Time Between Failure
- Maintenance Man-Hours per Flying Hour (objective only)
- Mean Flight Hours between Unscheduled Maintenance
- Mission-Capable Rate
- Full Mission Capable Rate
- False Alarm Rate

The MV-22, as configured and tested in OPEVAL, did achieve the thresholds for:

- Fault Detection
- Fault Identification
- Mean Turn Around Time
- Mean Corrective Maintenance Time

OPEVAL results for Mission Reliability were marginal, but met the JORD requirement. Additionally, the MTBF and False Alarm measures did not attain the improvement ("growth") curves projected by the V-22 program office at the initiation of OPEVAL.

The communications capabilities in the MV-22 do not provide needed interoperability with command and control elements and other forces. Further development and testing is required.

The aircraft did not have sufficient heating or cooling capability to maintain acceptable cockpit and cabin temperatures during operations at extreme temperatures ranging from 117 degrees F in desert operations to cruising at 18,000 ft. altitude where the outside air temperature was 23 degrees F.

Documentation was deficient during OPEVAL. Specifically, many aspects of both the NATOPS and of the Integrated Electronic Technical Manual were incomplete and inaccurate, contributing to the extra maintenance workload.

Although the Fault Detection rate and the Fault Identification rate exceeded requirements, the associated False Alarm rate was so high as to make the entire automated Diagnostics capability of little or no value.

The effectiveness of the V-22's vulnerability reduction features was demonstrated during the LFT&E program. Also, the following vulnerability reduction features were developed or integrated into the design as a direct result of LFT&E: redundant jam-proof actuators; run-dry gear boxes; improved composite wing structure and fuel tanks; dual, tandem swashplate actuators; damage-tolerant ballscrew conversion actuators; dry bay fire protection; self-sealing fuel tanks; and suction fuel system.

Early ballistic tests against the FSD aircraft identified a potentially serious cracking problem following a hit into the composite sponson fuel tank structure. The damage was significantly greater than expected, and was accompanied by fires under the fuselage floor and within the cargo/passenger area of the fuselage. The sponson structure was redesigned using a different epoxy resin as well as a revised graphite fiber laydown process and retested. The additional tests demonstrated that the cracking was significantly reduced, there were no fires, and was within the repair limits typically used for composite structures.

An aircraft battle damage repair (ABDR) team comprised of Navy depot personnel and USAF SOF maintenance NCOs evaluated the damage following each firing into the Static Test article. Their assessment found that the improved sponson design was within acceptable limits for field expedient repairs at the organizational level. A concern remains in the capability to repair damage to the passenger cabin walls. This relatively thin structure was damaged in nearly all of the sponson test shots with the ORD threshold threat. These walls are critical, load-bearing members of the aircraft structure. Live Fire testing demonstrated that the aircraft would be capable of returning to base following a hit to the sponsons. Damage to the cabin walls requires an engineering assessment of the damage and repair, by regulation. Therefore, repair of damage to the cabin wall cannot be accomplished at the organizational level because the required engineering support is not available at this level of maintenance. This issue will be addressed during a second phase of the ABDR program. However, this additional effort remains unfunded.

A new fire suppression technology, gas generator fire suppressors, was developed and demonstrated during the LFT&E program. These suppressors are a relatively small, lightweight, cost-effective fire suppression alternative, which utilize a non-ozone depleting compound and provide fire protection during peacetime operations as well as combat. This new technology, which was installed in the wings of the flight test aircraft, already is credited with extinguishing a fire caused by a mechanical failure in an aircraft before it caused serious structural damage, thereby preventing the loss of a test aircraft.

CONCLUSIONS, RECOMMENDATIONS AND LESSONS LEARNED

The loss of one of the OPEVAL aircraft in a fatal mishap was attributed to a phenomenon known as Vortex Ring State. It is essential that the V-22 technical and operational community understand the phenomenon of vortex ring state as it applies to the V-22. Successful mapping of this region must be accomplished via a program of flight test, wind tunnel testing, and modeling and simulation. Key elements of such needed testing are:

- exploring the flight envelope of the actual aircraft under equilibrium conditions to map the boundary of the effect,

- exploring the flight envelope of the actual aircraft under transient conditions of power and flight control inputs to determine the effect of such transients, and
- use of scale-model rotors in wind tunnels to characterize the airflow field surrounding the rotor system near the boundary of the phenomenon.

Additional testing under realistic sustained operational conditions must be performed to ensure that the mission reliability, maintainability, logistics burden, availability, interoperability, documentation, and diagnostic shortfalls reflected in OPEVAL are corrected. Unless corrected, these suitability shortfalls will impose an unacceptable burden (cost, manpower, mission reliability, and operational availability) on the operational fleet.

Waived requirements from the JORD should be incorporated at the earliest practical time. Follow-on operational testing should address the effect of these waived items and capabilities on overall operational effectiveness and suitability.

Several design changes were made as a direct result of the Live Fire test program. Development and demonstration of some of these vulnerability reduction features, such as those found in the sponsons and wing structure, required several iterations (test-fix-test) to achieve the desired characteristics.

Vulnerability modeling of ballistic events is still inadequate to predict aircraft and crew vulnerability and to identify potential design changes to reduce vulnerability to hostile fire. For instance, the existing models were not able to verify the actual capability of the vulnerability reduction features integrated into the V-22's design. These models require additional improvements, particularly those addressing warhead fuzing, fire initiation, explosions, and the performance of various fire suppression alternatives.

The V-22 program is developing a new, structural-analysis-based ABDR procedure that shows exceptional promise. This procedure provides for an aircraft damage assessment and triage to be carried out when a threat damaged aircraft returns to base. Commanders can then determine whether a damaged aircraft can continue to be used to support combat operations and under what load/speed/range restrictions or whether repair procedures or evacuation of the aircraft are required. In the past, when there was a doubt, a damaged aircraft would have been sidelined until depot repairs were made and certified. The ABDR effort has been severely constrained by a lack of funding. The Navy must ensure adequate funds are provided to complete the ABDR program for the V-22.