CH-53K – Heavy Lift Replacement Program

Executive Summary

- The Navy is testing in accordance with the DOT&E-approved Test and Evaluation Master Plan (TEMP) and a DOT&E-approved 2010 Alternative Live Fire Test and Evaluation (LFT&E) plan. The program has seven flyable aircraft to support integrated developmental and operational flight testing. The contractor has delivered three of the four System Development Test Articles (SDTA), all of which are participating in the test program. The seven flyable aircraft have flown 2,138.1 flight hours as of September 30, 2020.
- The Navy is implementing corrections to multiple design deficiencies discovered during developmental testing. These include: hot gas ingestion by the number 2 engine; low reliability of main rotor gearbox; hot gas impingement on aircraft structures; tail boom and tail rotor structural problems; overheating of main rotor dampers; high temperatures in the number 2 engine bay; and wheel brakes.
- The Program Office is preparing a Memorandum of Understanding for endorsement by Commander, Operational Test and Evaluation Force, Marine Corps Deputy Commandant for Aviation, and DOT&E that describes a three-period IOT&E test schedule. DOT&E is collaborating with the Navy and other stakeholders to determine the specific IOT&E entry criteria as part of the Operational Test Readiness Review process.
- In May 2020, the Navy restarted the LFT&E program after an 18-month delay caused by funding constraints. The Navy is currently executing live fire testing on the Ground Test Vehicle at China Lake, California, which is expected to be complete in July 2021. In conjunction with tail rotor flexbeam and installed armor testing, this will complete Phase I of the LFT&E testing.
- The Navy has neither funded nor adequately scoped Phase II of the LFT&E activities as required by the DOT&E-approved LFT&E plan and as necessary to fully assess the vulnerability of the aircraft against operationally realistic kinetic threats.

System

- The CH-53K is a new-build, fly-by-wire, dual-piloted, three-engine, heavy-lift helicopter slated to replace the aging CH-53E. The CH-53K is designed to carry 27,000 pounds of useful payload (three times the CH-53E payload) over a distance of up to 110 nautical miles, climbing from sea level at 103 degrees Fahrenheit to 3,000 feet above mean sea level at 91.5 degrees Fahrenheit.
- The CH-53K design incorporates the following survivability enhancements:

  - Large Aircraft Infrared Countermeasures with advanced threat warning sensors (combines infrared, laser, and hostile fire functions into a single system), an AN/APR 39C(V)2 radar warning receiver, and an AN/ALE-47 countermeasure dispensing system
  - Pilot armored seats, cabin armor for the floor and sidewalls, fuel tank inerting, self-sealing fuel bladders, and 30-minute run-dry capable gear boxes.
- The Navy intends the CH-53K to maintain a shipboard logistics footprint equivalent to that of the CH-53E.

Mission

Commanders employ the Marine Air-Ground Task Force equipped with the CH-53K for:

- Heavy-lift missions, including assault transport of weapons, equipment, supplies, and troops
- Supporting forward arming and refueling points and rapid ground refueling
- Assault support in evacuation and maritime special operations
- Casualty evacuation
- Recovery of downed aircraft, equipment, and personnel
- Airborne control for assault support

Major Contractor

Sikorsky Aircraft (a Lockheed Martin subsidiary company) – Stratford, Connecticut

Activity

- The Navy is testing in accordance with the DOT&E-approved TEMP and a DOT&E-approved 2010 Alternative LFT&E plan. The program has seven flyable aircraft to support integrated developmental and operational flight testing. The contractor has delivered three of the four SDTA, all of which are participating in the test program. The seven flyable aircraft have flown 2,138.1 flight hours as of September 30, 2020. SDTA-4, the last of the four aircraft for IOT&E, is scheduled to arrive at Marine Corps Air Station New River, North Carolina, in March 2021.
- The Program Office recovered the contractor test personnel shortfalls from FY19 and returned to full staffing by January 2020.
- The Navy has initiated several design changes to fix deficiencies discovered during testing:

Engine Integration

- The Navy identified engine exhaust gas re-ingestion (EGR) as a significant technical deficiency to be solved prior to IOT&E. In addition to EGR, the program addressed exhaust gas impingement on the skin of the aircraft. A third challenge related to EGR is engine bay overheating, which required improved airflow to cool without adversely affecting the ability to extinguish potential engine fires.
- The program selected several prototypes for fabrication and installation on flight test aircraft. Aircraft modifications began in October 2019, and initial developmental flight test events began in December 2019. The prototype designs will be installed on the IOT&E aircraft.

Main Gearbox (MGB)

- The program improved the design of the Main Gearbox (MGB) after qualification tests found the first Engineering Development Model MGB designs to be much less durable than required. The Integrated Test Team (ITT) installed the improved design MGB on one aircraft, and resumed flight testing in May 2019.

Tail Rotor Flexbeam

- Early tail rotor flexbeam composite material designs delaminated during flight test efforts. Sikorsky improved the flexbeam manufacturing process. The ITT installed the new flexbeam in May 2019 and returned to flight test.

Main Rotor Damper

- The dampers, which are designed to reduce vibration loads in the main rotor system, experienced load spikes due to several design characteristics. Sikorsky has redesigned the dampers, and additional design changes have been made after the ITT installed and tested the new dampers during FY20. Preliminary test results from hot environment testing are positive.

Intermediate Ground Mode during Aircraft Launch

- A failure condition occurred during flight test events when the aircraft transitioned from ground to flight. This condition could result in the pilots losing control of the aircraft. The program completed several design changes in the flight control software and added an override switch to allow the pilots to select the flight control laws manually prior to takeoff. The ITT began flight test events in February 2020.

Wheel Brakes

- The original wheel brake design used a two-stage master brake cylinder and close tolerance brake caliper to meet all requirements. This resulted in brake heating during taxi, excessive pedal travel, and unpredictable response when transitioning between stages. Sikorsky used modeling and simulation (M&S) as well as a full-scale component test at the brake supplier to determine that an accumulator system must be added to the system. Initial ground taxi tests resumed in September 2020.

- The ITT conducted developmental flight testing at sea aboard an Amphibious Assault Ship in June 2020. The test team conducted tests to verify the launch and recovery wind envelopes that were predicted by M&S. The test team conducted tests to determine wind conditions that have the potential to damage the aircraft during spreading and folding of the rotor blades. The test team collected data for Intermediate Ground mode software testing during the shipboard testing.
- The ITT completed developmental flight testing in Yuma, Arizona, as part of Degraded Visual Environment (DVE) and high ambient temperature testing. Testing was performed in full brownout conditions and with temperatures in excess of 115 degrees Fahrenheit. The Developmental Test report published on September 10, 2020, indicates engine performance degrades below acceptable minimums after 21 minutes of exposure to brownout conditions. The aircraft's operating manual limits permissible engine exposure to brownout during a maneuver to 70 seconds.
- The Program Office is preparing a Memorandum of Understanding for endorsement by Commander, Operational Test and Evaluation Force, Deputy Commandant for Aviation, and DOT&E that describes a three-period IOT&E test schedule. DOT&E is collaborating with the Navy and other stakeholders to determine the specific IOT&E entry criteria as part of the Operational Test and Evaluation Readiness Review process.
- The program has made a design change to the Aircraft Survivability Equipment (ASE) that relocates the Guardian Laser Turret Assemblies (GLTA) infrared jammers due to interference from the aircraft engine exhaust plume that could adversely affect the aircraft survivability equipment performance. The design change will not be available for the start of IOT&E Period 1. The ITT will test the new design on an EDM during IOT&E Period 2 at Naval Air Station (NAS) Patuxent River, Maryland, with support from VMX-1. VMX-1 will test the new design as installed on a production line aircraft during IOT&E Period 3 at Marine Corps Air Station (MCAS) New River, North Carolina.
- The ITT discovered Sikorsky Configuration Management (CM) errors that hampered flight test execution. Inaccurate CM logs for aircraft life-limited components led the HX-21

Commanding Officer to halt operations while the logs were audited. This caused a loss of approximately 3 weeks of flight test productivity.
- In 3QFY20, the Navy resumed live-fire testing of CH-53K on the Ground Test Vehicle (GTV) starting with fuel cell and sponson testing against threshold threats under cruise and hover conditions. GTV live-fire testing of fuel, hydraulics, drive, propulsion, flight controls, structure, and tail rotor systems will take place in two additional test periods in 1QFY21 and 4QFY21.
- Tail rotor blade ballistic testing, including testing of the redesigned tail rotor flexbeam and dynamic testing of post-ballistic articles under 30-minute fly-home loads, is scheduled to begin in November 2020.
- Manufacturer qualification ballistic testing of the cabin armor was completed in 4QFY20. Live-fire testing to evaluate the effectiveness of the armor against operationally representative kinetic threats is scheduled to occur in 1QFY21.
- The Program Office has continued to defer Phase II of the LFT&E program until after IOC. This testing, defined in the DOT&E-approved Alternate LFT&E Strategy, has not yet been fully funded.

Assessment
- Rebaselined projections estimate that IOT&E will begin in 3QFY21 due to technical problems that have extended System Design and Development beyond original projections.
- EGR testing led to additional, small changes to the prototype design solution. Once those changes were made, flight testing showed the design solution virtually eliminated exhaust reingestion by the engines. Sikorsky will incorporate the design changes into the production aircraft.
- CH-53K's advanced flight control software provides more control stability than older variants of the aircraft. Test data from the shipboard testing should result in a larger wind envelope for CH-53K.
- Transmission Time-Between-Overhaul will increase as the ITT conducts test events with the new MGB design installed and subsequent maintenance inspections are completed.
- Wheel Brakes have been a known issue for well over 2 years, and Sikorsky will have an interim design for IOT&E. DOT&E fully expects the operational testers will write one or more major deficiencies against the IOT&E brake design. Sikorsky has begun to work on a permanent, productionized brake.
- Engine performance degradation in brownout conditions will necessitate extremely frequent engine replacements and repair if the Marine Corps continues to train and operate in locations where brownout conditions are prevalent. CH-53K aircrew cannot realistically perform external cargo delivery operations within the 70-second operating limit.
- IOT&E aircraft are required to be production representative. The three-period IOT&E schedule described in the MOU will include testing on a low-rate initial production aircraft in Period 3.
- Sikorsky's CM systems are not fully integrated across the entire Sikorsky production and flight test databases. Configuration changes that are entered into one database do not promulgate throughout the rest of the configuration accounting databases. This results in inconsistent, inaccurate databases and aircraft log books, and has the potential for aircraft components to remain installed beyond their recommended life limits. Sikorsky has added manpower and funding to update their systems to better integrate the promulgation of updates across the CM enterprise.
- The ITT depends on consistent flight test execution to maintain progress toward IOT&E and allow newer flight test pilots and engineers to gain the experience necessary to conduct more complex flight test events.
- Phase II of the LFT&E program is essential for a complete survivability assessment of CH-53K against operationally relevant threats. This phase includes component tests for the main rotor assembly and tail rotor hub against threshold threats originally scheduled to support the Milestone C decision. Any deficiencies identified in this phase of testing will need to be resolved after Initial Operational Capability.

Recommendations

The Navy should:
1. Ensure Sikorsky adequately invests in the completion of CM enterprise improvements. Those improvements will have larger benefits in future programs, such as Future Vertical Lift.
2. Develop a sustainable FOT&E test program to evaluate deployment capabilities that will not be tested in IOT&E. The FOT&E test program should verify that any changes to the aircraft to correct deficiencies are effective and suitable.
3. Develop and fully fund Phase II of the LFT&E program as described in the DOT&E-approved LFT&E Strategy.
4. Continue to develop mitigations to address design deficiencies identified in test.