

C-5M

Executive Summary

- The C-5M program completed operational testing in January 2010. The modernized and re-engined C-5 aircraft, the C-5M, is operationally effective. The C-5M has the potential to increase the cargo carrying capacity of the fleet and offers new cargo delivery options not possible with the legacy system. The new engines provide enhanced capabilities for nonstop routes and increased flexibility with respect to routes, runways, and environmental conditions.
- The C-5M is not operationally suitable. The system's ability to conduct the strategic airlift mission was limited by deficiencies in the All-Weather Flight Control System, by problems with the Embedded Diagnostics System (EDS) and Built-In Test (BIT) functionality, by inadequate support equipment, and a lack of dedicated training systems. The C-5M did not achieve required wartime mission capable rates or logistics departure reliability, which affect the overall amount of cargo that can be delivered in a specific period of time. These shortfalls were not operationally significant.
- The C-5M is survivable in a low-threat environment. C-5M survivability in a medium-threat environment was not tested or assessed.
- The DOT&E Combined Operational and Live Fire Test and Evaluation report for the C-5 Reliability Enhancement and Re-engining Program (RERP), dated October 1, 2010, contains additional details.

System

- The C-5 is the largest four-engine, military transport aircraft in the United States. The C-5 has 36 pallet positions and can carry a maximum payload of 270,000 pounds. The typical C-5 crew size is seven.
- The C-5M designation is the result of two separate but related modernization efforts:
 - The Avionics Modernization Program (AMP) incorporates a mission computer, a glass cockpit with digital avionics



(including autopilot and auto-throttles), and state-of-the-art communications, navigation, and surveillance components for air traffic management.

- The RERP provides reliability enhancements, plus new commercial engines, nacelles, thrust reversers, and pylons.

Mission

- Units equipped with the C-5 perform strategic airlift, emergency aeromedical evacuation, transport of brigade-size forces in conjunction with other aircraft, and delivery of outside or oversize cargo (cargo that does not fit on a standard pallet).
- Units equipped with the C-5 execute missions at night, in adverse weather conditions, and in civil-controlled air traffic environments around the world. The units are capable of completing extended-range missions because the C-5 can receive in-flight aerial refueling.

Major Contractor

Lockheed Martin Aeronautics Company – Marietta, Georgia

Activity

- The Air Force completed the OT&E for the C-5M in January 2010, accumulating 1,333 flight hours. Additional OT&E data were collected through July 2010 from C-5M flight operations tasked by Air Mobility Command (AMC).
- The Air Force performed high tempo operations (415.9 flight hours) from a forward operating base (Naval Air Station Rota, Spain) from June 14, 2010 to July 15, 2010, utilizing the two currently available C-5M aircraft.
- DOT&E approved the Test and Evaluation Master Plan to support the Full-Rate Production decision in October 2010.
- DOT&E completed a Combined Operational and Live Fire Test and Evaluation report for the C-5 RERP on October 1, 2010.
- Developmental testing of software version 3.5 began in August 2010.

Assessment

- The C-5M is operationally effective. The new General Electric F138-GE-100 engines enhance the ability of the aircraft to deliver cargo. The increased thrust and modern

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- design of the new engines allowed the aircraft to meet the four Key Performance Parameters relating to engine performance: time to climb, one engine out climb gradient, noise compliance, and emission compliance.
- While the C-5M did not meet the predicted Million-Ton-Miles per Day (MTM/D) capability during OT&E, it could significantly increase the transported cargo capacity of the fleet. Since the new engines have increased performance over the legacy engines in all environmental conditions, this offers new scenario options not possible with the legacy system, such as overfly and nonstop routes.
 - The C-5M has several significant deficiencies, identified before OT&E, which persisted throughout testing and affected the ability to successfully accomplish missions without workarounds and additional aircrew workload:
 - Restricted use of thrust reversers in flight – until the thrust reversers can be deployed reliably in flight, there will be a limited capability for procedures such as emergency descent and some tactical operations and descents.
 - Auto throttles – overactive in cruise operations, especially during turbulent conditions; numerous pitch and speed changes occurred, in addition to the failure of the auto throttles to maintain commanded airspeed during critical phases of flight.
 - Environmental Control System – degraded performance because of the auto-throttle instability. During flight through turbulent air, overactive auto throttles affected the bleed air supply, resulting in little control over the ECS. This caused cabin pressure fluctuations and cabin temperatures dipped below 50 degrees Fahrenheit.
 - Communication, navigation, and surveillance/air traffic management capabilities – shortfalls affected aircrew workload and will eventually restrict global airspace access if unaddressed.
 - The C-5M is not operationally suitable. The system's ability to conduct the strategic airlift mission was limited by deficiencies in the All-Weather Flight Control System, by problems with the EDS and BIT functionality, by inadequate support equipment, and a lack of dedicated training systems.
 - Deficiencies in several aspects of C-5M support functions, identified before testing began, had a significant effect on the suitability, specifically the maintainability, of the aircraft, including:
 - BIT – a very high false alarm rate combined with the low fault isolation rate increased the time to troubleshoot and complete maintenance actions. BIT detections of critical faults did not meet the requirement of 99 percent during testing.
 - Training Systems and Devices – aircrew and maintainer training devices specific to the C-5M are not yet available. Simulators at the contractor facility and on-aircraft training are used to mitigate the lack of aircrew simulators. Maintainers are trained on the aircraft, which is restricted by the aircraft availability. Some maintenance personnel during the operational testing saw maintenance procedures and performed corrective actions for the first time because that training had not yet been accomplished.
 - Information Assurance – the C-5M is susceptible to the same information assurance problems as the C-5 AMP, KC-135, and C-17 aircraft. The additional risk from information operations on the EDS is low. The AMC is addressing the information assurance deficiencies in the interface of the EDS and the aircraft in the next block upgrade.
 - The RERP modification provided improvements in the reliability, maintainability, and availability of the C-5M aircraft.
 - The C-5M met three of the six reliability requirements successfully, including the mean times between inherent failures, unscheduled maintenance actions, and removals of the flight and engine instruments subsystems.
 - The rate of occurrence of unscheduled maintenance actions met the time requirements throughout the OT&E, as did the failure rate.
 - Adequate spares were available for the OT&E, and spares were rarely a cause of delays during the OT&E.
 - The C-5M is survivable in a low-threat environment. The Live Fire program did not test C-5M survivability in a medium-threat environment.
 - Analysis revealed hydraulic system failure to be the number one vulnerability. This is counter to other aircraft where dry bay fire is the number one vulnerability.
 - The C-5M's susceptibility to evaluated threats is high but the vulnerability (aircraft kill) is low.
 - Ullage inerting system tests showed the system reduces oxygen concentration to levels that prevent ullage explosions from ballistic threats.
 - The C-5M is vulnerable to wing leading and trailing edge dry bay fires. The current dry bay fire suppression system is ineffective against threat-induced fires in the wing leading edge bays. These fires could lead to mission abort or aircraft loss. Engine pylon ballistic tests demonstrated vulnerabilities to fires in the two dry bays that contain flammable materials. These fires could cause engine loss and potentially wing damage that would result in a mission abort.
 - Engine nacelle fire suppression systems are effective against fires resulting from engine failures, but were not tested against ballistic threat-induced fires.
 - The radio frequency vulnerability is low. Flight controls are entirely mechanical and hydraulic and are unaffected by radio frequency disturbances. Each of the four engines has dual redundant, radio frequency hardened, Fully Automated Digital Engine Controllers.

Recommendations

- Status of Previous Recommendations. The Air Force has made satisfactory progress on all but one of the previous recommendations. The Air Force needs to enhance the wing leading and trailing edge fire suppression system performance.

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- FY10 Recommendations. The Air Force should:
 1. Correct the deficiencies in the auto-throttles, environmental control system, thrust reversers, BIT, training, information assurance, EDS, technical orders, and engine support equipment to enable C-5M personnel to operate and maintain the aircraft as intended.
 2. Add dry bay fire suppression for the wing leading and trailing edge dry bays based on current technologies employed in the F/A-18E/F and P-8A aircraft.
 3. Add additional dry bay fire suppression systems into the engine pylons.
 4. Conduct ballistic testing to validate analysis results showing that C-5M hydraulics are vulnerable to man-portable air defense systems. Should test results validate the analysis, consider the addition of flight control system hydraulic line fluid shutoffs (fuses or hydraulic fluid reservoir level sensing and shutoff of damaged lines).
 5. Conduct analysis of engine nacelle fire suppression system effectiveness against ballistic threat-induced fires. External airflow from ballistic damage may prevent the system from suppressing ballistic threat-induced fires.
 6. Complete defensive system testing and certification to evaluate the C-5M survivability in a medium-threat environment.

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