Small Diameter Bomb (SDB) II

Executive Summary

- The Air Force began Multi-Service Operational Test and Evaluation (MOT&E) Phase I flight testing and live fire testing of the Small Diameter Bomb (SBD) II on the F-15E in June 2018, conducting a total of 31 drops in FY18. The Air Force conducted an additional 28 drops and completed MOT&E Phase I flight tests in May 2019. The Air Force plans to complete Integrated Flight Simulation (IFS) data validation and collection of additional cybersecurity data in FY20, which will complete the remaining tasks of MOT&E Phase I.
- MOT&E Phase I flight test missions built upon the capabilities demonstrated in Government Confidence Testing (GCT). This included demonstrating the ability to successfully engage a target with multiple weapons on a single pass, operate in all modes in a GPS-jamming environment, perform a commanded abort, employ an exclusion zone, and override the exclusion zone to engage a target.
- The Air Force awarded the Low-Rate Initial Production Lot 5 contract for 1,260 weapons (510 Air Force, 750 Navy) in December 2018.
- The Navy intends to begin operational testing (OT) using the F/A-18E/F in FY20. MOT&E Phase II will begin in FY21 and continue through FY22 with the Navy conducting flight testing using the F-35. The program will accomplish a Full-Rate Production decision upon completion of F-35 testing.
- Analysis of SDB II accuracy and lethality are ongoing. Initial analysis of MOT&E Phase I data shows that modifications made as a result of findings from GCT and developmental test have improved performance.
- The Air Force is advocating for operationally representative initiatives to streamline the cryptographic information delivery, loading, and verification process. The current process adversely affects the ability to employ the SDB II at standoff range.

System

- The SDB II is a 250-pound, air-launched, precision-glide weapon that uses deployable wings to achieve standoff range.
- The Air Force directed design of the SDB II to achieve the capabilities deferred from SDB I. Capability improvements include: a weapon datalink and multi-mode seeker.
- The weapon datalink allows post-launch tracking and control of the weapon, which provides standoff employment capability.

- In addition to a GPS and an Inertial Navigation System, to achieve precise guidance accuracy in adverse weather, the SDB II employs the multi-mode seeker, equipped with a millimeter-wave radar, imaging infrared sensor, and a semi-active laser guidance sensor.
- The Normal Attack (NA) mode is used primarily to strike mobile targets in adverse weather. The Laser Illuminator Attack (LIA) mode is used to guide the weapon to a laser spot generated by the launching aircraft or a third party source. The Coordinate Attack (CA) mode is used primarily to strike stationary targets and can be used in adverse weather.
- The SDB II incorporates a multi-function warhead (blast, fragmentation, and shaped-charge jet) designed to defeat armored and non-armored targets. The weapon can be set to initiate on impact, at a preset height above the intended target, or in a delayed mode.
- An SDB II-equipped unit or Joint Terminal Attack Controller (JTAC) will engage targets in dynamic situations and use a weapon datalink network to provide in-flight target updates, in-flight retargeting, weapon in-flight tracking, and if required, weapon abort.

Mission

Combatant Commanders will use units equipped with the SDB II to attack stationary and moving ground and littoral targets in adverse weather conditions at standoff ranges.

Major Contractor

Raytheon Missile Systems – Tucson, Arizona

Activity

- The Air Force MOT&E Phase I operational test flights using the F-15E began in June 2018 and completed in May 2019. In total, the F-15E released 59 weapons, encompassing 43 NA, 8 CA, and 8 LIA missions. The program flew the test plan-required 56 releases plus 2 additional releases due to hardware failures and 1 additional release, at DOT&E's request, based on a previously failed maritime target mission during GCT.
- During MOT&E Phase I, the Target Data Scoring Board (TDSB) assessed 3 weapons as no tests due to test

artificialities and 11 weapons as having experienced a free flight reliability failure, leaving 45 weapons employed reliably. Faulty guidance inputs provided by an unfielded and non-operationally representative JTAC system induced two of the free flight reliability failures, leading DOT&E to consider them no tests. This does not change the TDSB scoring. Based on the above, MOT&E Phase I demonstrated free flight reliability of 45 successes, 9 failures, and 5 no tests.

- The nine failures included:
  - An Inertial Measurement Unit (IMU) gyro failure
  - A dome failure after the ejected dome cover contacted the dome
  - Two instances of an electrical transient occurring after the dome cover was ejected
  - Two different cryptographic software problems
  - Three different algorithm/seeker problems that led to inadequate performance during those particular missions
- The program identified the root cause for all failures except the IMU gyro failure, analysis of which is ongoing. Additionally, the program is finalizing a change to the dome cover deployment logic to address the problem of the dome cover contacting the dome after ejection. The program has incorporated fixes to all other failure modes in the next weapon software release.
- During MOT&E Phase I, the Program Office completed 20 rounds of seeker captive flight tests (CFTs), resulting in over 2,260 target runs in a wide variety of terrain and environmental conditions. These tests logged over 483 hours of seeker operation without any failures.
- The program augmented the IFS model by incorporating the results of the 2,260 CFT runs as well as weapon flight tests. Raytheon released its IFS model verification and validation report in July 2017, and the Air Force Operational Test and Evaluation Center (AFOTEC) gave initial accreditation for its use during OT. Upon receipt of all Air Force MOT&E validation data from Phase I, AFOTEC will be able to make a final accreditation decision, which would allow a determination regarding SDB II operational effectiveness.
- Captive carry reliability testing (CCRT) is complete with over 2,000 hours of ground reliability testing and over 2,320 hours of flight test. The program will continue to collect captive hours during the Production Reliability Incentive Program that began with Lot 2 production-representative assets.
- The program redesigned the Air Turbine Alternator (ATA), which provides power to the SDB II fuse, to address a deficiency identified during a CFT failure. No ATA failures occurred during MOT&E Phase I.
- The Air Force collected cybersecurity test data during a Cooperative Vulnerability and Penetration Assessment in December 2018, and an Adversarial Assessment in February 2019.
- The Air Force collected cybersecurity test data from the Weapons System Simulator (WSS) and the Richter Laboratory F-15E bus emulator in July 2019. AFOTEC has not accredited the WSS as adequate for operational evaluation purposes because they were unable to gain the necessary verification and validation data from Raytheon within the FY18-19 MOT&E Phase I timeline and funding limitations.
- AFOTEC hosted a Sandia National Laboratory (SNL) Red Team at the Raytheon hardware-in-the-loop laboratory in September 2019. The SNL Red Team will publish a report of their analysis of seeker attack vectors in CY20.
- The Air Force awarded the Low-Rate Initial Production Lot 5 contract for 1,260 weapons (510 Air Force, 750 Navy) in December 2018.
- The Navy intends to conduct OT in FY20 to verify SDB II integration on the F/A-18E/F. The Navy is scheduled to conduct MOT&E Phase II in FY21 and FY22 on the F-35B and F-35C to further characterize its operational effectiveness against small boats, and to evaluate carrier/shipboard operability. Phase II will also include CFTs to provide additional data for employment against maritime targets.
- With the exception of accrediting the WSS, the Air Force conducted MOT&E Phase I testing in accordance with the DOT&E-approved Milestone C Test and Evaluation Master Plan (TEMP) and test plan.
- DOT&E intends to publish an MOT&E Phase I F-15E Early Fielding Report expected in 3QFY20.
- The Air Force and Navy are in the process of updating the Milestone C TEMP based on the results of MOT&E Phase I. This update will drive the specifics of F/A-18E/F OT and MOT&E Phase II.

Assessment

- MOT&E Phase I flight test missions built upon the capabilities demonstrated in GCT by showing the ability to successfully engage a target with multiple weapons on a single pass, operate in all modes in a GPS-jamming environment, perform a commanded abort, and both employ an exclusion zone and override the exclusion zone to engage a target.
- In the CA mode, the system performed as expected with all weapons hitting at appropriate distances from the planned coordinates provided to the weapon. In the LIA mode, all weapons hit in very close proximity to the directed laser spot.
- SDB II performance in NA mode continues to improve.
  - During GCT, the program implemented software improvements and modified employment procedures to correct deficiencies when engaging static targets in certain environments. MOT&E Phase I flight test missions confirmed the software improvements and modified employment procedures improved SDB II performance against static targets.
  - The weapon performs well in NA mode against moving targets if it receives valid targeting data. Two factors affected the weapon receiving valid targeting data during MOT&E Phase I: the cumbersome process for loading Link 16 datalink cryptographic information and the lack of a DOD standard JTAC ultrahigh frequency (UHF) datalink kit.
    - The process to load Link 16 datalink cryptographic information is cumbersome due to Net-Enabled Weapons

Handling Guidance requirements, which requires the cryptographic information be parsed out and hand-loaded to ensure security. There is no way to verify if the cryptographic information on the aircraft, weapons, and mission planning systems are valid and compatible with the datalink until mission time. During MOT&E, the program mitigated this limitation by developing and fielding Network Entry System Test (NEST) software, which advises the aircrew prior to launch as to whether all cryptographic information is loaded properly and compatible with the datalink. Additionally, subject matter experts reviewed datalink cryptographic information prior to launch. However, the NEST software is not operationally adequate and subject matter expert review is not operationally sustainable. Additional initiatives to streamline cryptographic information delivery, loading, and verification are required for SDB II to be effectively employed in standoff mode.

  - During testing, JTACs used multiple different UHF datalink kits. The lack of JTAC familiarity with the different kits, particularly their ability to ensure the kit was compatibly keyed to transmit data to the weapon, resulted in incorrect targeting data being passed to the weapon.
- Mission planning is also a significant challenge, with average planning times of over 50 minutes per weapon (the threshold time is 5 minutes per weapon). Much of this is related to a time intensive, error prone cryptographic data entry process, and a poor exclusion zone creation process.
- Weapons with the production-representative software version 7 demonstrated a reliability that is slightly below the threshold required at this stage of the program, but does mark a considerable improvement from early testing. The Program Office anticipates that the next software release will increase the reliability to greater than the threshold for all inventory assets. DOT&E will evaluate the reliability of these updated weapons during F/A-18E/F OT and MOT&E Phase II flight test missions.
- Preliminary lethality analysis indicates the weapon performs as expected against target surrogates for legacy main battle tank, infantry fighting vehicle, anti-aircraft gun, surface-to-air missile target-erector-launcher, rocket launcher, and small patrol boat. Detailed lethality analysis will be provided in the DOT&E Phase I F-15E Early Fielding Report.
- Continued comparisons of the IFS model pre- and post-flight predictions indicate the model is adequate for the kinematics flown in flight test to date. Raytheon continues to develop and update the IFS model, which will be essential to the assessment of the results of live fire and operational testing. The current IFS model only includes legacy small boat target data and does not contain data for modern small boat targets. The IFS, in combination with lethality and free flight reliability data, will produce single-shot kill probability values needed to assess end-to-end weapon effectiveness against a range of operationally relevant targets.

Recommendations

- The Air Force should:
  1. Improve the mission planning cryptographic data entry and exclusion zone creation processes to decrease the mission planning timeline.
  2. Characterize lethality against modern main battle tanks.
  3. Update the IFS to include signature data for modern small boat targets.
  4. Update the Milestone C TEMP, in conjunction with the Navy, to generate additional data points to validate NA effectiveness and to generate the remaining data needed to support an operational evaluation of the SDB II cybersecurity posture.
  5. Investigate options for standardizing JTAC UHF datalink kits for use in MOT&E Phase II.
- The DOD should:
  1. Advocate for operationally representative initiatives to streamline the cryptographic information delivery, loading, and verification process. Current Net-Enabled Weapons Handling Guidelines processes adversely affect the ability to employ the SDB II at standoff range.