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14. ABSTRACT

This document contains the Executive Summary of the final report for the USAF Test Pilot School Test Management Project Have Multi-path Escape Decisions Using Sophisticated Algorithms (Have MEDUSA). The full report is available under USAFTPS-TIM-18A-02 from the USAF TPS, Edwards AFB, CA. The Have MEDUSA report documents results for testing a system for real-time automatic ground collision avoidance for performance limited aircraft. Testing was requested by the Air Force Research Laboratory, Wright-Patterson AFB, Ohio. The lead developmental test organization was the Air Force Test Center, Edwards AFB, California. The executing test organization was the 412th Test Wing, Class 18A of the USAF Test Pilot School, Edwards AFB. Testing was conducted from 5 to 18 September 2018 and comprised of 2 ground test hours and 11 sorties totaling 19.9 flight test hours. Overall, the Rapidly Selectable Escape Trajectory (RSET) system was assessed to be MARGINAL. The RSET system performance demonstrated the utility of using a multi-path collision avoidance system for performance limited aircraft. Path prediction error did not meet the specified criteria and was larger than expected for the 30-second path predictions; however, at the maximum refresh rate of 12.5 Hz, the RSET system ensured terrain clearance in all cases tested.

15. SUBJECT TERMS
Have MEDUSA, Have ESCAPE, F-16, Multi-path, Rapidly Selectable Escape Trajectory (RSET), Trajectory Prediction Algorithm, Terrain Avoidance, Controlled Flight Into Terrain (CFIT), Auto-GCAS, Learjet, Flight Test

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EXECUTIVE SUMMARY

This report presents the results for the Have Multi-path Escape Decisions Using Sophisticated Algorithms (Have MEDUSA) test management project (TMP). The lead developmental test organization (LDTO) was the Air Force Test Center, Edwards AFB, California. The executing test organization (ETO) was Class 18A of the United States Air Force Test Pilot School (USAF TPS) working in partnership with Calspan Corporation, Buffalo, New York and the Air Force Institute of Technology (AFIT), Wright-Patterson AFB, Ohio. Testing was requested by the Air Force Research Laboratory, Wright-Patterson AFB, Ohio. Testing was performed in the Calspan Learjet 25D (LJ-25D) Variable Stability System (VSS), tail number N203VS, from 5 to 18 September 2018. Testing included 11 sorties and 19.9 flight hours in the R-2508 complex and 2 ground test hours under the job order number (JON) MT18A200.

A successfully implemented automatic ground collision avoidance system (Auto-GCAS) for performance limited aircraft, such as transports and bombers, will help mitigate future Air Force mishaps. Have MEDUSA used the Rapidly Selectable Escape Trajectory (RSET) system to predict terrain collision potential and automatically command appropriate ground avoidance maneuvers. The RSET algorithms used aircraft state and navigation information to predict escape maneuvers using five trajectory prediction algorithms (TPAs) which projected the aircraft path forward 30 seconds. The TPA maneuvers consisted of left and right 60° bank turns, left and right 30° bank climbing turns, and a wings-level climb. All five TPAs used a speed-scaled, g-limited, flight path angle control law designed for performance limited (Class III) aircraft as defined in *MIL-STD-1797B*. These five maneuvers were simultaneously compared to the surrounding Digital Terrain Elevation Database (DTED) terrain data, which was vertically biased to create a terrain safety buffer. When the RSET system predicted that all the TPA maneuvers would intersect the terrain safety buffer, the flight control system was commanded to execute the last previously open path. During this test the VSS, which could simulate various aircraft, was configured as a baseline LJ-25D.

The RSET system was flight tested at 15,000 ft PA, 8,000 ft PA, and 500 ft AGL, each at 220 and 270 KIAS. Entry conditions consisted of straight-and-level, climbing, descending, and turning attitudes. The system was manually activated by the test team via the center console system between the pilots and a laptop at the test conductor station. The system was automatically activated by DTED from a mountain in R-2508 which was virtually relocated to the aircraft position with a position and heading slewing tool. For safety, the Learjet was hand-flown in the vicinity of actual terrain to evaluate nuisance in the system with the RSET command link severed.

The overall test objective was to demonstrate the utility of the RSET system as a multipath Auto-GCAS for performance limited aircraft. All objectives were met.

Overall, the RSET system was assessed to be MARGINAL. The RSET system performance demonstrated the utility of using a multi-path collision avoidance system for performance limited aircraft. Path prediction error (PPE) did not meet the specified criteria and was larger than expected for the 30-second path predictions; however, at the maximum refresh rate of 12.5 Hz, the RSET system ensured terrain clearance in all cases tested. Incorrect accounting for wind drift effects, the Learjet VSS auto-trim feature, and the low fidelity engine model were possible sources of PPE. The test team recommended the main sources of PPE be determined prior to further testing. Despite the simple design of the control logic, the RSET system was able to achieve and maintain target load factor and flight path angle with momentary overshoots. The RSET system response was in line with the timely and aggressive characteristics desirable for Auto-GCASs. The system showed no tendency for nuisance activations for all cases tested. The RSET hand-back implementation utilized was immature and the Learjet VSS safety trips were repeatedly triggered. Despite the unrefined hand-back, the response was deemed favorable in most cases and could be utilized as a baseline for future Auto-GCAS implementations.