Designation: F2585 – 08

Standard Specification for
Design and Performance of Pneumatic-Hydraulic Unmanned Aircraft System (UAS) Launch System[1]

This standard is issued under the fixed designation F2585; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the design and performance of unmanned aircraft system (UAS) launch system operating via a closed-loop pressurized hydraulic or pneumatic system with a hydraulic recovery, or both.

1.2 In instances where the launcher and UAS manufacturer are the same entity, compliance with this specification is the responsibility of the UAS manufacturer where applicable.

1.3 *This standard does not purport to address all of the safety concerns associated with the USA launch system and its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *Military Standard:*[2]
MIL-STD-882 Standard Practice for System Safety

3. Terminology

3.1 *Definitions:*

3.1.1 *acceleration envelope*—range of launch accelerations (that is, acceleration curves) that the UAS launcher is capable of generating.

3.1.2 *deployed configuration*—UAS launcher's physical geometry in which it is in neutral position and ready for launch operations. Any manufacturer-prescribed check-out tests have been completed when the UAS launcher is in deployed configuration.

3.1.3 *gaseous charging agent*—compressible fluid that is pressurized to store the energy required for launch.

3.1.4 *jerk*—first derivative of the acceleration curve with respect to time; also referred to as acceleration growth rate.

3.1.5 *launch actuator*—cylinder that accepts the gaseous charging agent or liquid charging agent during expansion of the gaseous charging agent to move a piston; transfers gas or fluid pressure into an accelerating force on the shuttle assembly.

3.1.6 *launch, or exit, velocity*—velocity of the UA upon release from the launcher; UAS take-off velocity.

3.1.7 *launch lock*—mechanism that secures the shuttle assembly into the launch position to counter the force from fully pressurized pre-launch accumulator(s).

3.1.8 *launch rail*—track upon which the shuttle assembly can be accelerated prior to UA take-off.

3.1.9 *launch system*—self-contained system capable of launching a UA at prescribed take-off conditions; also referred to as a launcher or catapult.

3.1.10 *launch weight*—maximum allowable UA take-off weight not including the weight of the shuttle assembly.

3.1.11 *liquid charging agent*—incompressible fluid that can be used to fill the pre-launch accumulators to move the piston.

3.1.12 *neutral position*—UAS launcher system state in which *(1)* any fluids inside the pre-launch accumulators and pre-charge accumulators (if available) are at equal pressures, or *(2)* the system does not apply a force on the launch lock mechanism.

3.1.13 *power transmission mechanism*—used to transfer the accelerating force from launch actuator to shuttle assembly (for example, a shuttle assembly ram, cable and pulley system, etc.); power transmission mechanism may not be necessary in designs in which the launch actuators moves the shuttle assembly directly.

3.1.14 *pre-charge accumulator(s)*—similar in design to the pre-launch accumulator; allows extra space for storing gaseous charging agent between launches at a pressure lower than operating pressure; also used to achieve desired pre-launch accumulator pressures despite fluctuations in ambient temperatures.

3.1.15 *pre-launch accumulator(s)*—stores the energy required for launch; typically consists of either *(1)* a cylinder with a piston separating fluids (gaseous charging agent and liquid charging agent) within which a compressible fluid (usually a gas) is pressurized by pumping an incompressible

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[2] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

fluid (usually hydraulic) into the cylinder, or *(2)* a pressurized container (for example, bottle) holding the gaseous charging agent with no piston (examples of each are provided in Fig. 1).

3.1.16 *recovery*—method by which the shuttle assembly is returned upon release of the UAS.

3.1.17 *shuttle assembly*—platform that interfaces with both the UA and the launcher.

3.1.18 *stowed configuration*—UAS launcher's smallest volumetric physical geometry in which the UAS launcher can be transported or stored for later use.

3.1.19 *stroke*—distance traveled by the shuttle assembly as measured from start (pre-launch) to UA release.

3.1.20 *throw weight*—total weight to be accelerated by the UAS launcher; UA weight plus shuttle assembly weight.

3.1.21 *UA surrogate*—structure representative of the mass and support point dimensions of the UA; used to interface with the shuttle assembly during test launches.

3.1.22 *unmanned aircraft (UA)*—flight-capable portion of the unmanned aircraft system (UAS).

3.1.23 *velocity envelope*—range of launch velocities that the UAS launcher is capable of generating; a function of launcher acceleration and rail length.

3.1.24 *weight envelope*—range of launch weights that the UAS launcher is capable of accelerating to the required take-off velocity.

4. Design

4.1 The hydraulic or pneumatic launcher with hydraulic recovery, or both, shall include, but not be limited to, the following main components: pre-launch accumulator(s), launch actuator(s), shuttle assembly, launch rail, and launch lock.

4.2 *Accumulator(s), Launch Actuator(s), and Power Transmission Mechanism:*

4.2.1 Each pre-launch accumulator shall be capable of pressurization to accommodate the range of ambient temperatures within which the UA is rated to be launched.

4.2.2 Each pre-launch accumulator shall be capable of pressurization that exceeds the maximum required pressurization of the weight and velocity envelopes by 25 %.

4.2.3 The gas used as a charging agent shall be:

4.2.3.1 Non-combustible or have low combustibility (for example, nitrogen, air),

4.2.3.2 Non-toxic, and

4.2.3.3 Capable of pressurization via a compressor or gas bottle.

4.2.4 The liquid charging agent shall have a viscosity range with maximum fluctuation as a function of ambient temperature such that:

4.2.4.1 It can generate the required range of velocities within the velocity envelope, or

4.2.4.2 It can be heated to acceptable temperatures if ambient temperatures are shown to potentially increase viscosity to levels that adversely affect the velocity envelope.

4.2.5 The piping that transfers the liquid charging agent shall be designed to minimize cavitation and ensure smooth flow from the accumulators to the launch actuator.

4.2.6 The launch actuator shall transfer gas pressure from the pre-launch accumulator(s) into an accelerating force on the power transmission mechanism.

4.2.6.1 Indirectly (that is, pre-launch accumulator transfers pressure from compressed gas into fluid pressure and is connected to the launch actuator via hydraulic pipes, or hoses, or both), or

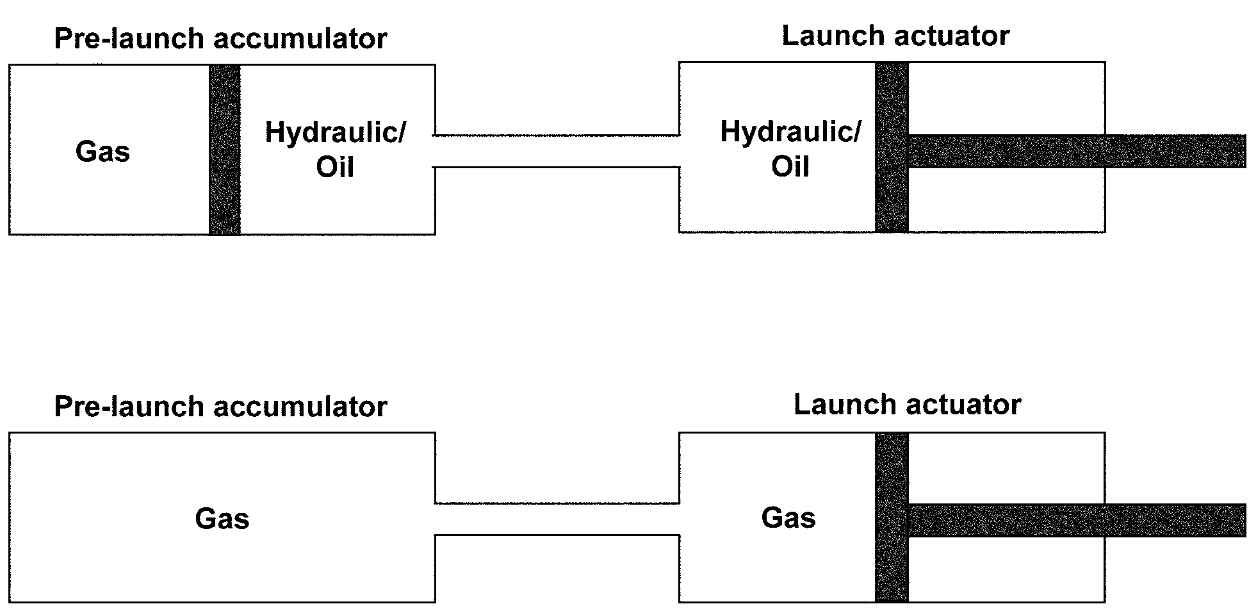

FIG. 1 Examples of Launcher Designs

4.2.6.2 Directly (that is, pre-launch accumulator is connected to the launch actuator via pneumatic pipes, or hoses, or both).

4.2.7 Pressurization to control launch velocity shall be adjustable by one person via electronic or mechanical controls. Pressurization shall be displayed to the launcher operator via an electronic or standard pressure gauge.

4.2.8 The hydraulic recovery system shall be designed to:

4.2.8.1 Utilize the same actuators used to generate the accelerating force, or

4.2.8.2 Have dedicated actuators used for recovery only.

4.3 *Shuttle Assembly, Launch Rail, and Launch Lock:*

4.3.1 The shuttle assembly shall be securable in start (pre-launch) position using a launch lock mechanism when the UAS launcher is in neutral position.

4.3.2 The launch lock mechanism shall be capable of withstanding 1.5 times the force generated by fully-pressurized pre-launch accumulators.

4.3.3 Launch shall be initiated with the release of the launch lock, allowing for acceleration of shuttle assembly (piston in the case of ram design) and UA. Accelerating force generated by launch actuator(s) can act on shuttle assembly directly or via power transmission mechanism.

4.3.4 The force (that is, acceleration) delivered through a power transmission mechanism to the shuttle assembly:

4.3.4.1 Shall be constant, or

4.3.4.2 When this force is not constant, the launcher manufacturer shall provide the operator with data showing the launcher acceleration curve.

4.3.5 The launcher system shall include a measurement device(s) to monitor maximum velocity of the shuttle assembly (that is, UA exit velocity).

4.3.6 Shuttle assemblies that interface with various UA platforms shall interface with the launch rail via a common (that is, universal) design such that no structural reconfiguration of the launcher is required to launch a given UA platform provided that UA falls within the launcher velocity and weight envelopes.

4.3.7 The launcher shall be configurable so that it can be oriented azimuthally to accommodate adjustment for:

4.3.7.1 Local obstacles,

4.3.7.2 Prevailing wind direction, and

4.3.7.3 Operational requirements.

4.3.8 The launcher shall be configurable so that it can be oriented in elevation to ensure that the take-off path (angle) is consistent with the performance of the UA.

4.4 *General Design and Performance:*

4.4.1 The launch system manufacturer shall coordinate closely with the specific UAS manufacturers and operators before and during the design process to tailor the launch system to the specific UA performance, structural, and operational requirements to include the UA:

4.4.1.1 Mass,

4.4.1.2 Required take-off velocity,

4.4.1.3 Maximum acceleration loads, and

4.4.1.4 Launch angle.

4.4.2 Launchers shall be designed and classified as a function of their weight, velocity and acceleration envelopes. Various UA shall be accommodated by a single launcher if the launcher fulfills the UA requirements listed in 4.4.1.1 through 4.4.1.4.

4.4.3 Launcher operation shall not be dependent upon compatibility with the UAS command or control data link.

4.4.4 Any resulting recoil of the launcher during the launch process shall be reacted by:

4.4.4.1 Shock absorbers on the launcher platform,

4.4.4.2 Secure grounding to prevent launcher movement under recoil loads, or

4.4.4.3 Other methods demonstrated to be able to absorb recoil.

4.4.5 The launcher system shall be a "closed" system with the self-contained capability for:

4.4.5.1 Power,

4.4.5.2 Fluid compression, and

4.4.5.3 Autonomous monitoring of launcher status.

4.4.6 The launcher generator may be capable of providing excess electrical power to other UAS systems on a contingency basis.

4.4.7 Velocity envelopes shall be achieved without the requirements for rocket-assisted take-off (RATO) or other propulsive devices.

4.4.8 The launcher system shall be designed to support operations in night or low light conditions.

4.5 *Proof of Compliance*—The manufacturer(s) of the launcher shall coordinate with the UAS manufacturer and operator to obtain concurrence on an acceptable means of compliance with these specifications in accordance with Section 5. Compliance may be proven by conservative testing with the UA or a UA surrogate.

5. Testing

5.1 Each launcher that is designed and built to UAS manufacturer specifications shall be tested prior to delivery to the UAS manufacturer.

5.2 The results of any developmental or acceptance testing shall be presented to the UAS manufacturer upon launcher system delivery. Any system modifications based on test results shall be documented and noted at this time.

5.3 *Developmental Testing:*

5.3.1 Where applicable as determined by the launcher manufacturer, the following test procedures shall be developed and performed on a prototype launcher in order that the manufacturer may determine the appropriateness for use, of not only the components, but the entire system of a newly designed launcher.

5.3.1.1 Procedures to verify such design characteristics as relevant deflections, loads, and forces that are placed on both the launcher and the UA during operation.

5.3.1.2 Procedures to determine velocity, weight, and acceleration envelopes generated by nominal launcher operation.

5.3.1.3 Procedures to allow the manufacturer to determine such factors as component variability and certification requirements of components.

5.3.1.4 Procedure to determine operational limits and restart criteria related to environmental conditions (that is, criteria to determine when previously exceeded operational and environmental conditions have returned to acceptable levels for nominal launcher operation).

5.4 *Acceptance Testing:*

5.4.1 Where applicable as determined by the launcher manufacturer and UAS operator, the following test procedures shall be developed and performed to determine launcher performance prior to delivery.

5.4.1.1 *Pressurization Time*—The initial time required to pressurize the launcher from atmospheric or neutral position pressure to launch pressure.

5.4.1.2 *Reload Time*—The time to recharge the launcher for subsequent launches.

5.4.1.3 *Weight (Mass) Envelope*—The regime of acceptable UA launch masses from minimum to maximum.

5.4.1.4 *Velocity Envelope*—The regime of acceptable UA launch velocities from minimum to maximum.

5.4.1.5 *Acceleration*—The acceleration curves and maximum possible acceleration generated by the launcher.

5.4.2 For the purposes of this testing, acceleration values shall be:

5.4.2.1 Measured using accelerometers having a bandwidth of at least DC-100 Hz,

5.4.2.2 Collected using a sampling frequency greater or equal to 500 Hz, and

5.4.2.3 Determined by low pass filtered or averaged data as agreed upon between the launcher manufacturer and the UAS manufacturer.

5.4.3 The number of test launches with UA surrogates shall be agreed upon between the launcher and UAS manufacturers prior to design acceptance.

5.4.3.1 The final velocity of the shuttle assembly with the UA surrogate shall be demonstrated to be within predefined limits of the programmed take-off velocity. This velocity shall have been previously agreed upon between UAS manufacturer and launcher manufacturer prior to initial launcher delivery.

5.4.3.2 The weight of UA surrogates shall be within ±5 % of the actual UA.

5.4.3.3 Aerodynamic forces (lift, thrust, drag) associated with the launch of the actual UA shall be estimated by conservative analysis or data from the UAS manufacturer and incorporated into the launcher's designated velocity envelope.

5.5 *Operational Testing:*

5.5.1 The launcher manufacturer shall develop specific operational tests along with maximum intervals for these tests to be performed that will allow the UAS operator to determine whether the launcher is performing within prescribed limits.

5.5.2 All operational tests, except those necessarily recommended subsequent to the launcher delivery because of information not reasonably available to the manufacturer at the time of delivery, should be recommended to the UAS operator at the time of delivery. All tests, whether recommended at the time of delivery, or subsequent tests, shall meet the following criteria:

5.5.2.1 All tests shall have been satisfactorily performed by the manufacturer prior to delivery.

5.5.2.2 The tests must be such that the launcher can reasonably be expected to pass during the expected design life, assuming recommended maintenance and operating procedures have been followed.

5.5.2.3 All tests must be reasonable and such that the UAS operator can reasonably be expected to be competent to perform (see Section 9).

5.5.2.4 Any operational test including load testing performed on the launcher shall be completely nondestructive in nature.

5.5.2.5 Any acceptance or operational testing conducted on the launcher shall be accomplished within the rated limits of the information provided by the manufacturer (see Section 10).

5.5.3 The launcher shall only launch UA in areas approved for UAS launch and flight operations. This does not apply to test launches of non-flight capable UA surrogates.

5.5.4 A minimum of one-person shall be designated with the sole responsibility to monitor the launcher's restricted area (that is, down-range area and launcher vicinity) during the UA launch sequence. This responsibility includes:

5.5.4.1 Initial clearing actions within the restricted area that should begin at the beginning of a nominal launch sequence and be performed at 5-min intervals until launch is complete or stood down, and

5.5.4.2 Continued vigilance to restrict access to the restricted area to only authorized personnel as prescribed in the launcher check list.

5.5.5 The UAS operator shall ensure that the cleared launcher downrange area is bounded by an arc ±90° from the launcher's longitudinal (that is, centerline) axis of symmetry. Swept through this arc is the downrange distance required for:

5.5.5.1 The launched UA to reach an altitude of 500 ft above ground level (AGL), and

5.5.5.2 The launched UA to change its heading by 90° from the launcher's take-off heading (that is, launch rail direction) for UA that cannot climb to 500 ft AGL.

6. Training

6.1 The launcher manufacturer shall make available a launcher operator training course incorporating:

6.1.1 Pneumatic launcher theory, design, and testing (example topics in Sections 4 and 5), and

6.1.2 Pneumatic launcher operation, safety (including warnings and labels), and maintenance (example topics in Sections 7 and 8).

6.2 A training course covering nominal, safe launcher operations shall not exceed five days in duration.

6.3 Training, operator and maintainer, shall be based upon knowledge, skills, and abilities approach.

7. Operations

7.1 With respect to the nominal launch sequence, the launch phase shall begin with the charging of the pre-launch accumulator(s) and end when the shuttle assembly no longer physically supports the weight of the UA (that is, it is airborne).

7.2 The launch system shall be accompanied with a checklist that provides the launch operator a prescribed set of procedures to be followed during each launch sequence to ensure that launch equipment and personnel meet the applicable safety and operations specifications specified herein.

7.3 The launch system shall be capable of operating in atmospheric conditions similar to those in which the UA is certified to be launched (for example, temperature, precipitation, humidity, particulate levels, etc. at the launch area).

8. Safety

8.1 A system safety analysis shall be performed in accordance with a CAA recognized process such as MIL-STD-882 to identify and mitigate, where possible, system hazards in the design.

8.2 The launcher system shall not require the use or storage of explosive materials for operation.

8.3 The launcher system shall not store explosive or other combustible materials in its stowed configuration without:

8.3.1 Written notification in the operating manual as part of the stowed configuration description, and

8.3.2 Warning text on the launcher that is visible to the launcher operator in both the stowed and deployed launcher configurations.

8.4 Other than the UA, the launcher shall not eject any solid material or structure beyond the launcher footprint unless the area has been cleared in accordance with 5.5. To prevent the shuttle assembly from creating a hazard, a braking system shall be employed to slow the shuttle assembly for UA take-off velocities greater than 50 knots.

9. Maintenance and Reliability

9.1 The launcher manufacturer shall provide such training and manuals necessary for launcher personnel to perform routine inspections and maintenance in the field of operation including but not limited to an operating manual.

9.2 Unless otherwise agreed to between the launcher and UAS manufacturer, all training, manuals, and other written material (including gauges and warning labels on the launcher) shall be in English, and all numerical values shall be provided in English and metric units.

9.3 *Inspections:*

9.3.1 The UAS operator shall conduct annual launcher system inspections to be performed by the launcher manufacturer or a manufacturer-trained individual.

9.3.2 The launcher manufacturer shall designate the inspection interval for any pressurized components of the launcher (tanks, lines, valves, etc.) for integrity and leaks.

9.3.3 New information or newly recommended inspections or testing that were not available at the time of launcher delivery shall be provided by the launcher manufacturer to the UAS operator as supplemental notification bulletins. The first pages of these bulletins shall also contain the following information, as available:

9.3.3.1 The name, address and telephone number of the manufacturer,

9.3.3.2 The date the bulletin is released,

9.3.3.3 The date the bulletin takes effect,

9.3.3.4 The period the bulletin recommends for completion of any prescribed action,

9.3.3.5 The name under which the launcher was delivered to the UAS operator,

9.3.3.6 The model number or name of the launcher,

9.3.3.7 The applicable dates of manufacture for the affected launcher(s),

9.3.3.8 A number that uniquely identifies the bulletin,

9.3.3.9 The number of any superseded bulletins, if any, and

9.3.3.10 The appropriate title on the first page of the bulletin in large bold upper case letters:

(1) "SAFETY ALERT" for notifications that recommend immediate action.

(2) "SERVICE BULLETIN" for notifications that do not recommend immediate action but do recommend future action.

(3) "NOTIFICATION" for notifications that do not necessarily recommend future action but are primarily for promulgation of information.

9.4 *Maintenance:*

9.4.1 The launcher manufacturer shall provide, with delivery of launcher, documented maintenance instructions. These instructions shall include, but not be limited to, the following:

9.4.1.1 Description of launcher operation, including the function and operation of major components,

9.4.1.2 Description of the recommended procedures for setup to the deployed and disassembly to the stowed launcher configuration,

9.4.1.3 Description of any sensitive areas on the launcher, and recommended procedures for inspection and maintenance of these areas, subsequent to launcher set-up,

9.4.1.4 Schematics of electrical power, lighting, controls, and other systems, including location charts where applicable, to include:

(1) Description of any recommended maintenance procedures for electrical components,

(2) The name of the component manufacturer and appropriate identification number or specifications, or both, for electrical components used within the launcher, and

(3) Each electrical component used within the launcher that has an individual identification number, symbol, or code to facilitate its location and identity on the electrical schematics.

9.4.1.5 Schematics and documentation of hydraulic and pneumatic systems, including:

(1) Recommended nominal pressures,

(2) Location of components,

(3) Line specification,

(4) Fitting specification,

(5) Type of fluid,

(6) Manufacturer's troubleshooting guide, and

(7) Recommended routine maintenance procedures.

9.4.1.6 Any recommended maintenance procedures to be followed in the event of an extended period of launcher storage (greater than 15 days).

9.4.2 Routine launcher maintenance shall be capable of being performed by the UAS launcher operator before or after nominal launch sequences.

9.4.3 Routine maintenance shall be defined as any scheduled mechanical assessment, addition, or modification to the launcher system to maintain the system's:

9.4.3.1 Current level of performance, and

9.4.3.2 Current level of safety.

9.4.4 Non-routine maintenance shall be defined as any non-scheduled mechanical assessment, addition, or modification to the launcher system to maintain the system's:

9.4.4.1 Current level of performance, and

9.4.4.2 Current level of safety.

9.4.5 Replacement parts for launcher components shall be:

9.4.5.1 Obtained from the original manufacturer of the launcher, using the appropriate manufacturer-supplied identifying nomenclature,

9.4.5.2 Produced using appropriate original manufacturing drawings or specifications and procedures, and

9.4.5.3 Changes to the design or manufacturing-specific criteria shall be documented and approved by the original launcher manufacturer or another qualified engineer before systems, components, or subcomponents are placed into use on the launcher.

9.5 *Reliability:*

9.5.1 Launcher maintenance cycles shall not decrease overall UAS availability by more than 10 %.

9.5.2 The launcher system mean time between failure (MTBF) shall not be lower than the MTBF of the UAS.

9.5.3 The launcher systems shall provide a clear means to alert the operator regarding its operational status to indicate:

9.5.3.1 Fully functional status, and

9.5.3.2 Diagnostic information if the system is not fully functional.

9.5.4 Diagnostic information required in 9.5.3.2 shall not be used as a substitute for routine inspections (see 9.3).

9.6 *Proof of Compliance*—The reliability of any launcher design or component upon which overall UAS safety or reliability is dependent shall be proven by conservative analysis, test with a UA surrogate, or a combination of both and done with coordination between the launcher manufacturer and UAS manufacturer or operator.

10. Support

10.1 The launcher manufacturer shall be available to offer field support to UAS launcher operators as needed for a period that includes up to the tenth UAS field launch.

10.2 Additional support (annual inspections, non-routine maintenance, additional or specialized personnel training, etc.) shall be arranged separately from the initial launcher procurement.

10.3 The launcher manufacturer shall provide with the delivery of each launcher a specification sheet that includes the following technical data and information:

10.3.1 Minimum UA take-off weight,

10.3.2 Maximum UA take-off weight,

10.3.3 Minimum launcher pitch angle,

10.3.4 Maximum launcher pitch angle,

10.3.5 Operating temperature range,

10.3.6 Minimum UA take-off velocity,

10.3.7 Maximum UA take-off velocity,

10.3.8 Average launcher set-up time (that is, from fully stowed configuration to deployed configuration) based on at least five trials, with manpower specified,

10.3.9 Average launcher recovery time (that is, time required after the launch of one UA to ready the launcher for a subsequent launch, not including the time required to load the subsequent UA onto the launcher) based on at least five trials, with manpower specified,

10.3.10 Acceleration profile with UA or surrogate loaded in accordance with 5.4.1.5,

10.3.11 Launcher weight without UA,

10.3.12 Launcher dimensions, stowed and deployed,

10.3.13 A mass-velocity envelope plot representing information similar to that shown in Fig. 2, and

10.3.14 A profile detailing noise levels for all phases of launcher operation.

11. Keywords

11.1 catapult; launch; take-off; UA; UAS; unmanned aircraft system

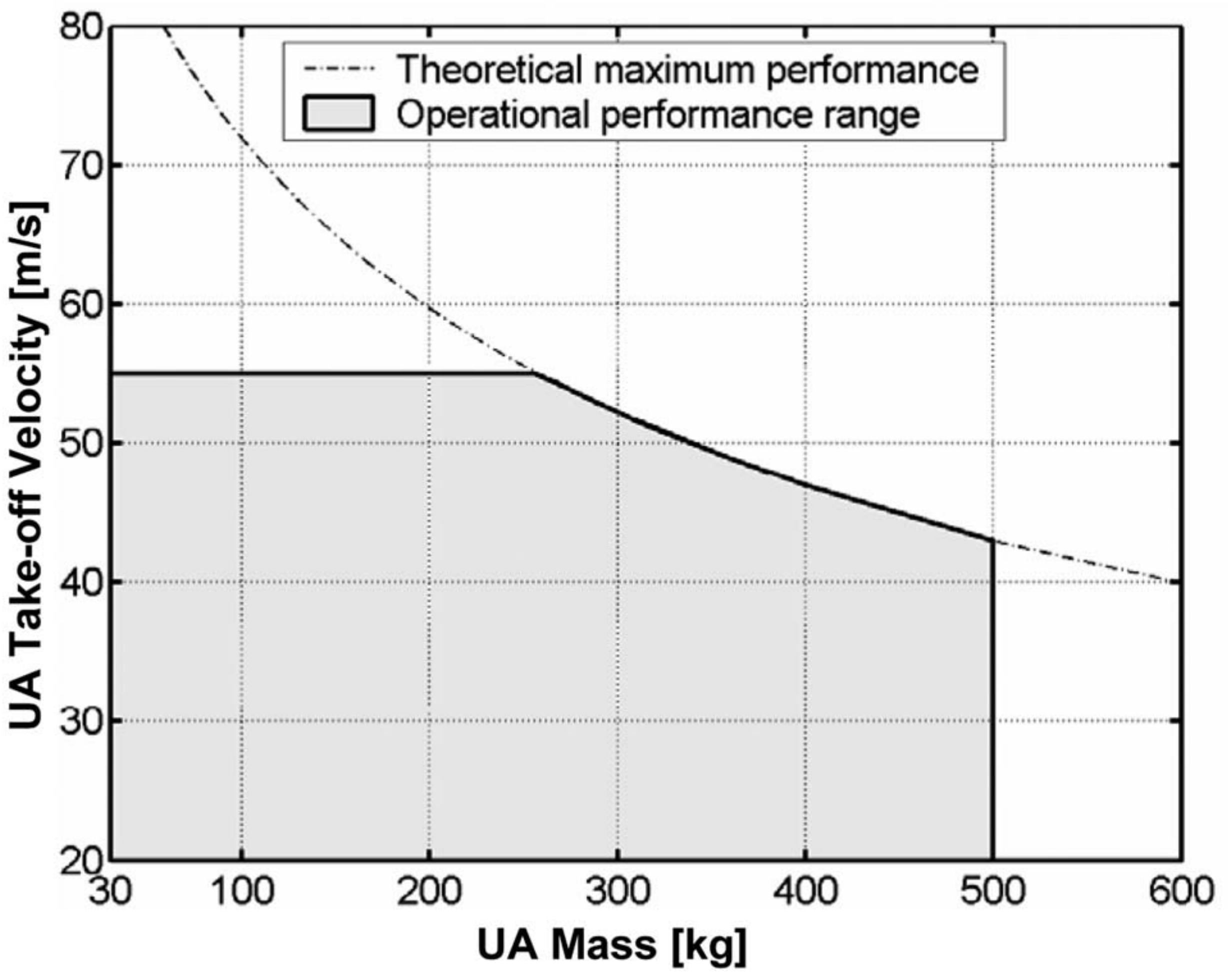

FIG. 2 Example of UA Mass versus Exit Velocity