DATA ITEM DESCRIPTION

Title: AIR VEHICLE TECHNICAL DESCRIPTION REPORT FOR ROTORCRAFT AND PROPELLER-DRIVEN FIXED-WING AIRCRAFT

Number: DI-SESS-82291
Approval Date: 20190918
AMSC Number: 10057
Limitation: N/A
DTIC Applicable: No
GIDEP Applicable: No
Preparing Activity: AV
Project Number: SESS-2019-013
Applicable Forms: N/A

Use/relationship: This Data Item Description (DID) specifies the technical data and supplementary technical data necessary for Government assessments of the flight performance, stability and control, handling qualities, rotor dynamics, airframe dynamics, engine/drive system response characteristics, and transportability characteristics of new design or derivative rotary-wing and propeller-driven fixed-wing aircraft. These evaluations and analyses are used to support the substantiation of aircraft airworthiness in accordance with (IAW) Army Regulation (AR) 70-62 (Copies of this AR are available from armypubs.army.mil.), and to support Government technical analyses IAW Federal Acquisition Regulation (FAR) 15.404-1(e). (Copies of this reference are available from www.acquisition.gov/browse/index/far.)

The Air Vehicle Technical Description Report will be included in the rotorcraft's or propeller-driven aircraft's Government record of airworthiness substantiation IAW AR 70-62.

This DID is applied in the solicitation and contract for all phases of system acquisition. Sections applicable to the acquisition will be identified by the buying activity by tailoring this DID in DD Form 1423, Contract Data Requirements List (CDRL). Updates to the report will be as specified as part of the DID tailoring activity.

This DID contains the format, content, and intended use information for the data deliverable resulting from the work task described in the solicitation or contract.

Requirements:

1. Reference Documents. The applicable issue of the documents cited herein, including their approval dates and dates of any applicable amendments, notices, and revisions, shall be as specified in the solicitation or contract.

2. Format. Multimedia report formatting shall be in accordance with (IAW) American National Standards Institute/National Information Standards Organization (ANSI/NISO) Z39.18. (Copies of this reference are available from www.niso.org or the National Information Standards Organization, 3600 Clipper Mill Rd, Ste. 302 Baltimore, MD 21211-1950.)

2.1 Volumes. The report shall be divided into separate volumes based on contractually-specified Data Marking IAW Defense Federal Acquisition Regulation Supplement (DFARS) 252.227-7013(f) (Copies of this reference are available from https://www.acq.osd.mil/dpap/dars/dfarspgi/current/index.html), Distribution Statement IAW Department of Defense Instruction (DODI) 5230.24 (Copies of this reference are available from http://www.esd.whs.mil/DD/), and security classification level IAW the contractually-specified Classification Guide.

2.2 Report Documentation Page. The report and each separate appendix and annex shall include a Standard Form (SF) 298 Report Documentation Page.

2.3 Interchange Medium. The multimedia report shall be composed and delivered in computer-readable files for inclusion in Department of Defense Model-Based Enterprise information systems. Digital file formats shall comply with open standards to future-proof file access.

2.4 System of Measurement. The Report shall use either the International System of Units (SI; meter-kilogram-second) system of measurement, the British Gravitational Units (BG; foot-slug-second) system of measurement, or SI units followed by equivalent BG units in parenthesis. The system of measurement shall be used consistently throughout the report and all attachments.

2.4.1 Measurement Unit Abbreviations, Acronyms, and Symbols. Abbreviations and acronyms for units of measurement shall be IAW American Society of Mechanical Engineers (ASME) Y14.38 (Copies of this reference are available from www.asme.org or ASME Information Central Orders/Inquiries, P.O. Box 2300, Fairfield, NJ 07007-2300.). Letter symbols for units of measurement shall be IAW Institute of Electrical and Electronics Engineers (IEEE) Std 260.1 (Copies of this reference are available from www.ieee.org or IEEE Service Center, 445 Hoes Ln, Piscataway, NJ 08854-1331.).

2.5 Engineering Design Data. Engineering design data shall conform to ASME Y14.24, ASME Y14.41, and ASME Y14.100 standards for accuracy, legibility and clarity. (Engineering design data is defined IAW MIL-STD-31000, Technical Data Packages, as engineering drawings, Three Dimensional Intelligent (3Di) viewables, native Computer-Aided Design (CAD) models, neutral CAD models or a combination of these, which define the physical and/or functional requirements of an item by means of graphic and textual presentations. Engineering design data shall be included in the multimedia report as computer-readable entities IAW MIL-STD-31000. Digital formats for data exchange shall comply with open standards to future-proof access.

2.6 CAD Solid Models. Native or neutral CAD solid models shall be included in the multimedia report as computer-readable entities IAW MIL-STD-31000. Digital formats for data exchange shall comply with open standards to future-proof access.

2.7 Airfoil Sections.

2.7.1 Section Profiles. Plots shall use an expanded vertical scale, or 'whale plot' for clarity. Each section profile shall include a table of coordinates. Not less than 50 points on both the upper and lower surfaces shall be included in the table; at least 20 of these points shall be within the first 20 percent of the airfoil chord. Point clustering shall be used to resolve curvature or sharp discontinuities in surface topology.

2.7.2 Two-Dimensional (2D) CAD Models. Native or neutral 2D CAD shrink-wrap models of airfoil sections shall be included in the multimedia report as computer-readable entities IAW MIL-STD-31000. 'Non-Uniform Rational B-Spline' (NURBS) CAD entities shall be used to digitally represent airfoil section contours for data exchange. The airfoil section profiles shall be watertight for use in creating viscous computational fluid dynamics (CFD) meshes. Digital formats for data exchange shall comply with open standards to future-proof access.

2.8 Automatic Flight Control System (AFCS) Digital Models. AFCS digital models shall include a graphical representation of the AFCS algorithmic model in MATLAB/Simulink™ or equivalent computer-readable format. Digital formats for data exchange shall comply with open standards to future-proof access.

2.9 Animations/Video. Digital formats for animations and video shall comply with open standards to future-proof media playback.

2.10 Graphs. The size and scale used for graphic presentations are a function of the data to be presented. Axis scales shall facilitate interpolation (i.e., scale increments shall facilitate reading data directly from the graph).

2.11 Tables. Tabulated data shall consist of machine-encoded text that may be retrieved by automated information systems without the use of intermediate optical character recognition software. The exact format of the table is a function of the variables to be tabulated. Data discretization shall allow linear interpolation between points. If tabulated data are lengthy, more than 2 pages, and complicate understanding or interpretation they shall be placed at the end of the Report in numeric order.

2.11.1 Mass Properties. Data shall include weights, center of gravity (CG) locations, and moments of inertia per Table I.

Table I. Mass Properties Data

Rotor Blades	GW(1)	CG			Moments of Inertia					
		SL(2)	BL(3)	WL(4)	I_x(5)	I_y(6)	I_z(7)	I_{xy}(8)	I_{xz}(9)	I_{yz}(10)

(1)GW: Gross weight
(2)SL: Stationline ordinate
(3)BL: Buttline ordinate
(4)WL: Waterline ordinate
(5)I_x: Mass moment of inertia about the aircraft roll axis
(6)I_y: Mass moment of inertia about the aircraft pitch axis
(7)I_z: Mass moment of inertia about the aircraft yaw axis
(8)I_{xy}: Product of inertia of mass about the aircraft roll and pitch axes
(9)I_{xz}: Product of inertia of mass about the aircraft roll and yaw axes
(10)I_{yz}: Product of inertia of mass about the aircraft pitch and yaw axes

2.12 Mathematical Symbols and Equations. Fonts shall comply with open standards to future-proof computer display.

2.13 Body Text. The main textual content of the report and each separate appendix and annex shall consist of machine-encoded text that may be searched and indexed by automated information systems without the use of intermediate optical character recognition software. Fonts shall comply with open standards to future-proof computer presentation.

2.14 Airfoil Aerodynamic Data in C81 File Format. American Standard Code for Information Interchange (ASCII) text files of tabulated airfoil nondimensional aerodynamic lift, C_l, drag, C_d, and pitching moment, C_m, data as a function of angle of attack, α, and Mach number, Ma, shall be included in the report as computer-readable media. The 'C81 airfoil file format' is a structured table format for airfoil aerodynamic data that is used by many rotorcraft analysis computer programs. Table II describes the C81 airfoil file format. 'Record' denotes separate lines in the file. The format does not allow blank lines between Records; hence, unused Records are not included. The file shall not contain tab characters or other unprintable characters within Record fields to the left of column 73. Data Markings or comments must be confined to the right of column 72 or below the last Record.

Table II: C81 File Format for Airfoil Aerodynamic Data

COLUMN	DATA ELEMENTS
Record 1: Description and Table Sizes	
1-30	Identifying text.
31-32	Number of *Ma* entries in the C_l table. (Minimum of 2; maximum of 99).
33-34	Number of α entries in the C_l table. (Minimum of 2; maximum of 99).
35-36	Number of *Ma* entries in the C_d table. (Minimum of 2; maximum of 99).
37-38	Number of α entries in the C_d table. (Minimum of 2; maximum of 99).
39-40	Number of *Ma* entries in the C_m table. (Minimum of 2; maximum of 99).
41-42	Number of α entries in the C_m table. (Minimum of 2; maximum of 99).
Record 2: Ascending values of *Ma* for the C_l table.	
1-7	(blank)
8-14	*Ma* entry.
15-21	*Ma* entry.
22-28	*Ma* entry (if needed).
29-35	*Ma* entry (if needed).
36-42	*Ma* entry (if needed).
43-49	*Ma* entry (if needed).
50-56	*Ma* entry (if needed).
57-63	*Ma* entry (if needed).
64-70	*Ma* entry (if needed).
Record 2A, 2B, 2C…: Repeat of Record 2 format, as needed for continuation.	
Record 3: -180° α value, and C_l values for *Ma* from Record 2	
1-7	α entry.
8-14	C_l entry for the intersecting values of α and *Ma*.
15-21	C_l entry for the intersecting values of α and *Ma*.
22-28	C_l entry for the intersecting values of α and *Ma* (if needed).
29-35	C_l entry for the intersecting values of α and *Ma* (if needed).
36-42	C_l entry for the intersecting values of α and *Ma* (if needed).
43-49	C_l entry for the intersecting values of α and *Ma* (if needed).
50-56	C_l entry for the intersecting values of α and *Ma* (if needed).
57-63	C_l entry for the intersecting values of α and *Ma* (if needed).
64-70	C_l entry for the intersecting values of α and *Ma* (if needed).
Records 3A, 3B, 3C…: Continuation lines for Record 3 (if needed).	
1-7	(blank)
8-14	C_l entry for the intersecting values of α and *Ma*.
15-21	C_l entry for the intersecting values of α and *Ma* (if needed).

22-28	C_l entry for the intersecting values of α and *Ma* (if needed).
29-35	C_l entry for the intersecting values of α and *Ma* (if needed).
36-42	C_l entry for the intersecting values of α and *Ma* (if needed).
43-49	C_l entry for the intersecting values of α and *Ma* (if needed).
50-56	C_l entry for the intersecting values of α and *Ma* (if needed).
57-63	C_l entry for the intersecting values of α and *Ma* (if needed).
64-70	C_l entry for the intersecting values of α and *Ma* (if needed).
Records 4, 4A, 4B, 4C…: Repeat of Records 3, 3A, 3B, 3C…, formats for ascending values of α, up to and including the +180° α entry.	
Record 5: Ascending values of *Ma* for the C_d table.	
1-7	(blank)
8-14	*Ma* entry.
15-21	*Ma* entry.
22-28	*Ma* entry (if needed).
29-35	*Ma* entry (if needed).
36-42	*Ma* entry (if needed).
43-49	*Ma* entry (if needed).
50-56	*Ma* entry (if needed).
57-63	*Ma* entry (if needed).
64-70	*Ma* entry (if needed).
Record 5A, 5B, 5C…: Repeats of the Record 5 format, as needed for continuation.	
Record 6: -180° α value and C_d values for *Ma* from Record 5	
1-7	α entry
8-14	C_d entry for the intersecting values of α and *Ma*.
15-21	C_d entry for the intersecting values of α and *Ma*.
22-28	C_d entry for the intersecting values of α and *Ma* (if needed).
29-35	C_d entry for the intersecting values of α and *Ma* (if needed).
36-42	C_d entry for the intersecting values of α and *Ma* (if needed).
43-49	C_d entry for the intersecting values of α and *Ma* (if needed).
50-56	C_d entry for the intersecting values of α and *Ma* (if needed).
57-63	C_d entry for the intersecting values of α and *Ma* (if needed).
64-70	C_d entry for the intersecting values of α and *Ma* (if needed).
Record 6A, 6B, 6C…: Continuation lines for Record 6, as needed.	
1-7	(blank)
8-14	C_d entry for the intersecting values of α and *Ma*.
15-21	C_d entry for the intersecting values of α and *Ma* (if needed).
22-28	C_d entry for the intersecting values of α and *Ma* (if needed).
29-35	C_d entry for the intersecting values of α and *Ma* (if needed).
36-42	C_d entry for the intersecting values of α and *Ma* (if needed).
43-49	C_d entry for the intersecting values of α and *Ma* (if needed).
50-56	C_d entry for the intersecting values of α and *Ma* (if needed).

57-63	C_d entry for the intersecting values of α and *Ma* (if needed).
64-70	C_d entry for the intersecting values of α and *Ma* (if needed).
Records 7, 7A, 7B, 7C…: Repeat of Records 6, 6A, 6B, 6C… format, for ascending values of α, up to and including the +180° α entry.	
Record 8: Ascending values of *Ma* for the C_m table.	
1-7	(blank)
8-14	*Ma* entry.
15-21	*Ma* entry.
22-28	*Ma* entry (if needed).
29-35	*Ma* entry (if needed).
36-42	*Ma* entry (if needed).
43-49	*Ma* entry (if needed).
50-56	*Ma* entry (if needed).
57-63	*Ma* entry (if needed).
64-70	*Ma* entry (if needed).
Record 8A, 8B, 8C…: Repeats of Record 8 format, as needed for continuation.	
Record 9: -180° α value and C_m values for *Ma* from Record 8	
1-7	α entry
8-14	C_m entry for the intersecting values of α and *Ma*.
15-21	C_m entry for the intersecting values of α and *Ma*.
22-28	C_m entry for the intersecting values of α and *Ma* (if needed).
29-35	C_m entry for the intersecting values of α and *Ma* (if needed).
36-42	C_m entry for the intersecting values of α and *Ma* (if needed).
43-49	C_m entry for the intersecting values of α and *Ma* (if needed).
50-56	C_m entry for the intersecting values of α and *Ma* (if needed).
57-63	C_m entry for the intersecting values of α and *Ma* (if needed).
64-70	C_m entry for the intersecting values of α and *Ma* (if needed).
Record 9A, 9B, 9C…: Continuation lines for Record 6, as needed.	
1-7	(blank)
8-14	C_m entry for the intersecting values of α and *Ma*.
15-21	C_m entry for the intersecting values of α and *Ma* (if needed).
22-28	C_m entry for the intersecting values of α and *Ma* (if needed).
29-35	C_m entry for the intersecting values of α and *Ma* (if needed).
36-42	C_m entry for the intersecting values of α and *Ma* (if needed).
43-49	C_m entry for the intersecting values of α and *Ma* (if needed).
50-56	C_m entry for the intersecting values of α and *Ma* (if needed).
57-63	C_m entry for the intersecting values of α and *Ma* (if needed).
64-70	C_m entry for the intersecting values of α and *Ma* (if needed).
Records 10, 10A, 10B, 10C…: Repeat of Records 9, 9A, 9B, 9C… format, for ascending values of α, up to and including the +180° α entry.	

2.15 Engine Performance Description. Documentation shall include uninstalled engine static performance data referred to the International Standard

Atmosphere Sea-Level Standard (ISA SLS) condition for a representative sample of applicable shaft speeds as illustrated by Table III. Power level definitions used include Maximum Continuous Power (MCP; continuous power/torque limit), Intermediate Rated Power (IRP; 30 minute power/torque limit), Maximum Rated Power (MRP; 10 minute power/torque limit), and Contingency Rated Power (CRP; 2.5 minute power/torque limit).

Table III: Engine Performance Data

Power Setting	Total Temperature at Engine Face	Total Pressure at Engine Face	Total Airflow	Maximum Specific Fuel Consumption	Rated Output Shaft Speed	Minimum Specific Shaft Power	Rated Output Torque	Net Jet Thrust
CRP								
MRP								
IRP								
MCP								
75% MCP								
50% MCP								
25% MCP								
Flight Idle								
Ground Idle								
Reverse (if applicable)								

3. Content. The Air Vehicle Technical Description Report shall include the following:

3.1 Vehicle Configuration.

3.1.1 Conceptual Level. The Conceptual Level subdivision is defined IAW MIL-STD-31000 as design concepts with additional information required for analysis and evaluation.

3.1.1.1 Engineering Design Data.

a. Inboard profile and layout views of the air vehicle in vertical take-off and landing (VTOL) mode (if applicable). The views shall include overall layout, dimensions, clearances, and operating parameters (e.g., rotor shaft angle(s), fixed aerodynamic surface angle(s)).

b. Views illustrating vehicles that change configuration during normal flight operation (e.g., tilting rotors, wings, or ducts; movable control surfaces; variable-sweep wings; swiveling tail rotor/propulsor(s); stopped rotor(s); folded/stowed rotor(s); deployable armament and launchers).

c. Views used to illustrate other modes (e.g., running takeoff or landing, cruise-flight mode for a tail-sitter).

d. Views used to document overall layout, dimensions, and clearances for the aircraft when folded and stowed to minimize volume required for deck or hanger parking, air and ship transport, long-term storage, etc.

3.1.1.1.1 Locations. Locations shall be marked on the appropriate view(s) in the aircraft standard stationline (SL), buttline (BL), and waterline (WL) coordinate system. Marked locations shall include:

a. Origin and orientation of the aircraft standard coordinate system.

b. Forward and aft ends of the fuselage, flight-ready, in-flight, and folded/stowed for storage/transport.

c. Heights of lowest and tallest features (excluding alighting gear and rotating blades), flight-ready, in-flight, and folded/stowed for storage/transport.

d. Lateral extent(s) of the widest features, excluding alighting gear, rotating blades, and foldable/removable portions of fixed aerodynamic surfaces.

e. Shaft center of rotation of each rotor.

f. Rotor/propulsor shaft tilt/swivel axis and the center of gravity (CG) of the tilting/swiveling mass (if applicable).

g. Aerodynamic center for each fixed aerodynamic surface.

h. Fixed aerodynamic surface tilt axis and the CG of the tilting mass (if applicable).

i. Hinge line locations for aerodynamic control surfaces (e.g., flaps, ailerons, rudders, elevators).

j. Fixed aerodynamic surface leading-edge flap(s) and slat(s).

k. Fixed aerodynamic surface winglets.

l. The centerline, CG, and notional shape representation of engine(s), motor(s), transmission(s), battery(s), internal armament, and any other major items.

m. Emergency egress openings.

n. Integral/bladder and discrete fuel tank(s).

o. Auxiliary fuel tank(s), internal and external, fixed and removable.

p. Fueling point(s).

q. Aerial refueling probe.

r. Engine inlet(s) and exhaust(s).

s. External inlet air filtration and particle separation device(s). A-kit (fixed) and B-kit (removable) components shall be clearly delineated for removable devices.

t. External exhaust infrared and acoustic signature control device(s). A-kit and B-kit components shall be clearly delineated for removable devices.

u. Avionics and mission equipment compartment(s).

v. Stores bay door(s), showing both open and closed configurations.

w. Each internal store carriage station, showing both deployed and retracted configurations.

x. Each external store station.

y. Sensor and weapon turret/dome(s), showing range of motion(s), if applicable.

z. Alighting gear, showing both deployed and retracted configurations.

aa. The ground plane (alighting gear unloaded; loaded at Maximum Ground Weight IAW SAWE RP-7; and kneeled.

ab. Aircraft folding hinge lines for storage/transport.

ac. Any points of contact between the aircraft surface and a transport ship/aircraft loading ramp crest/toe for a 15° ramp inclination; alighting gear loaded at transportation configuration weight and kneeled. (Refer to 4.4 of MIL-STD-1366, Interface Standard for Transportability Criteria, transport ships, and Appendix B of MIL-STD-1791, Designing for Internal Aerial Delivery in Fixed Wing Aircraft, for transport aircraft.)

ad. Pilots' sightlines, both forward and to the side.

ae. Air Data System measurement probes (e.g., pitot probes, pitot-static probes, static ports, thermometers).

af. Sensors.

ag. Antennas.

ah. External lights (both illumination and navigation).

ai. Wirecutter(s).

aj. Hoists.

ak. External cargo hook(s).

al. Chaff and flare dispensers.

am. Kittable external stores support system(s), clearly delineating both A-kit and B-kit components.

an. Boundary-layer control devices (e.g., vortex generators, strakes, fences, notches, diverters).

ao. CG location(s) for associated static turnover, tip-back, and tip-forward limits.

3.1.1.1.2 Dimensions. Data shall include dimensions shown on view(s) to include the following:

a. The radius of each unique rotor.

b. The root cutout radius of each unique rotor.

c. The static precone angle for each rotor.

d. The longitudinal and lateral shaft tilt angles or angular range (with respect to a vertical axis perpendicular to the reference WL plane) of each unique rotor shall be indicated.

e. The span of each fixed aerodynamic surface.

f. Mean aerodynamic chord of each fixed aerodynamic surface.

g. The angle (or angular range) of incidence (with respect to the fuselage reference longitudinal, lateral, and vertical axes) of the aerodynamic reference line of each fixed aerodynamic surface.

h. Dimensions and angular orientations of winglets.

i. The hinge line angle for aerodynamic control surfaces (e.g., flaps, ailerons, rudders, elevators).

j. The span of each aerodynamic control surface (e.g., flaps, ailerons, rudders, elevators).

k. The chord of each aerodynamic control surface (e.g., flaps, ailerons, rudders, elevators).

l. The angular range of motion for each aerodynamic control surfaces (e.g., flaps, ailerons, rudders, elevators).

m. The translational range of motion for each aerodynamic control surfaces (e.g., slats, Fowler flaps).

n. Horizontal and vertical distance(s) between rotor shaft center(s) and the aerodynamic center of fixed aerodynamic surface(s).

o. The minimum static and dynamic (rotors turning) clearances of the closest rotor blade(s) with respect to the rest of the air vehicle and the ground plane, for allowable aircraft configurations, weights, and CG locations that produce the minimum clearances.

p. Balance-point angles for static turnover, tip-back, and tip-forward limits.

q. The air vehicle overall length, width and height in hover and cruise mode(s), and folded and stowed for ship/air transport or storage.

r. Alighting gear track and tread plus the SL and BL location of the center of each ground-contact patch.

s. Alighting gear dimensions and travel, including skid, wheel, and strut dimensions, for both unloaded and condition for maximum loading per gear (i.e., the combination of weight and CG location that produces the greatest loading for each gear).

t. The maximum airframe width (without fixed aerodynamic surfaces), with alighting gear both retracted and extended.

u. The static and dynamic (limit-sink-speed landing) clearances of the closest non-rotating components with respect to the ground or deck (to include slope landings and rolling ship decks) for allowable aircraft configurations, weights, and CG locations that produce the minimum clearances.

v. Sensor and weapon turret/dome dimensions.

w. Range of motion of non-fixed external armament.

x. Door dimensions.

y. Non-door emergency egress opening dimensions.

z. Crew compartment nominal dimensions.

aa. Avionics and mission equipment compartment nominal dimensions.

ab. Cargo compartment nominal dimensions.

ac. Ramp dimensions.

ad. Maximum ramp cresting angle. (Refer to 4.4 of MIL-STD-1366 for additional details.)

ad. Weapons bay door dimensions.

ae. Weapons bay nominal dimensions.

af. Retractable alighting gear door dimensions.

ag. Retractable alighting gear well nominal dimensions.

ah. Engine inlet boundary layer diverter dimensions.

ai. Boundary-layer control device dimensions (eg. vortex generators, strakes, fences, notches, diverters).

3.1.1.2 Tabular Data.

3.1.1.2.1 Airframe. Tables associated with the engineering design data views shall include the following data as applicable.

a. Horizontal and vertical projected frontal areas of the complete air vehicle and the following mutually exclusive components: fuselage, boom(s), sponsons, nacelle(s), pylon(s), rotor hub fairing(s), and propeller spinner(s).

b. Wetted outer mold line areas of the complete air vehicle and the following mutually exclusive components: fuselage, boom(s), sponsons, nacelle(s), pylon(s), rotor hub fairing(s), and propeller spinner(s).

c. Volume coefficients of empennage surfaces.

d. Volume coefficients of canard surfaces.

3.1.1.2.2 Stability and Control Derivatives. Data IAW 2.11 shall be provided for hover and cruise in the Primary Mission configuration for SDGW and MGTOWs (if different), and at the allowable minimum Landing Gross Weight(s). (Configuration and weight definitions shall be as specified in the system performance specification, or in SAWE RP-7.) The methodology used to obtain the derivatives shall be described.

3.1.1.2.3 Fuel Tanks. Tables shall include the following data:

a. Capacities of each integral/bladder fuel tank.

b. Capacities of each discrete fuel tank.

c. Capacities of each auxiliary fuel tank (both fixed and removable).

d. Minimum Fuel on Deck (MFOD) quantity for each tank. (The MFOD is defined as the sum of the minimum fuel quantity per tank that will maintain continuous fuel pickup at the aircraft's allowable extreme hover/landing-maneuver pitch and roll attitudes, and the measurement uncertainty associated with the tank's fuel quantity gauging system. Note: MFOD as defined here is different from Unusable Fuel as documented in Weight Report submittals due to variability in aircraft trim attitude.)

3.1.1.2.4 Mass Properties. Data IAW 2.11.1 above shall include mass properties data for the following configurations and weights as defined in the system performance specification, or in SAWE RP-7 otherwise:

a. Primary Mission configuration.

b. The configuration used to define Structural Design Gross Weight (SDGW).

c. Configurations used to define allowable Maximum Gross Takeoff Weights (MGTOW; e.g., vertical takeoff, running takeoff, shipboard takeoff).

d. Allowable Maximum Landing Gross Weights (e.g., vertical landing, run-on landing, shipboard landing).

e. Allowable Minimum Landing Gross Weights.

f. All other configurations that define allowable limit weights during flight.

g. The aircraft folded and stowed for transport/storage.

3.1.2 Developmental Level. IAW MIL-STD-31000, the Developmental Level subdivision is defined as a specific design approach, the fabrication of prototype materiel for test or experimentation, and limited production. Data shall include design maturity updates to Conceptual Level data items in addition to the following items:

3.1.2.1 Air Vehicle Description.

3.1.2.1.1 Engineering Design Data. Data shall include the following:

a. Layout views showing shapes and clearances of engine(s), motor(s), transmission(s), battery(s), fuel cell(s), internal armament, and any other major items.

b. View(s) of the vehicle's wetted-outer-mold line surface that allow cross-section profile views to be extracted at points of significant changes in shape.

3.1.2.1.1.1 Dimensions, Areas, and Volumes. The following items shall be clearly noted on the appropriate engineering design data entities:

a. Projected frontal areas of the configuration from all orthographic directions.

b. Areas for wetted surfaces.

c. Cargo compartment dimensions.

d. Usable cargo compartment floor area.

e. Volume of the crew compartment.

f. Volume of all avionics and mission equipment compartments.

3.1.2.1.2 Tabular Data.

3.1.2.1.2.1 Stability and Control Derivatives. Data IAW 2.11 above shall include the effects of variation of configuration/mode (e.g., tilting rotor or tail sitter aircraft in VTOL or cruise mode), GW, CG location, and control surface deflections.

3.1.2.1.2.2 Stores Mass Properties. Data IAW 2.11.1 above shall include data for all stores that will be mounted in carriage on fixed aerodynamic surfaces IAW the system performance specification. Discrete entries shall include all allowable permutations where items may be expended by integer values (e.g., missile load-outs for missile launchers and rocket load-outs for rocket pods). Ranges of values shall be documented for items from which mass may be consumed (effectively) continuously (e.g., fuel from external fuel tanks and ammunition rounds from external gun pods).

3.1.2.2 Structure Engineering Design. Data shall include scaled (not isometric) cross-sectional views. The following details and dimensions shall be included in the views:

a. Wing – Structural box including: box chord and thickness along the span; typical cross sections showing flaps, ailerons, slats, etc., with control-surface hinge line pivots, actuator-to-control surface pivots, and actuator-to-base pivots locations marked; engine location and centroids; dimensions, areas, and center of mass for flaps, slats, ailerons, spoilers, etc., dimensions and areas for leading edge, trailing edge, major cutouts, etc.; fences, vortex generators, winglets; fold and production joints; materials used; and high-temperature areas, with design temperatures. Areas shall be shown in square feet and identified by cross hatching or other equivalent marking.

b. Empennage/Canard – Engineering design data and information compatible with wing requirements in 3.1.2.2.a above.

c. Rotor – Hub and hinge, including method of rotor attachment, typical cross section including any balance weight, structural box, rotor chord and thickness along the span. Blade area shall be expressed in square feet and identified by cross hatching or other equivalent marking.

d. Fuselage, hull, and booms – Primary and secondary structure including bulkheads, frames, longerons and stringers, major cutouts, flooring, major fittings and splices; pressurized area including volume, materials, and high-temperature areas, with design temperatures indicated. Fuel tank areas shall be cross hatched and capacities indicated, where not shown on a separate fuel system engineering design data view. Major cutouts, weapons bays, store provisions, engine, engine compartment, access doors, alighting gear support and cutout shall be marked and labelled.

e. Nacelle – Primary and secondary structure. Details shall be compatible with wing and fuselage requirements in 3.1.2.2.a above and 3.1.2.2.d above.

f. Air induction system – For purposes of clarity, details shall be included on either a separate engineering design data unit, on the fuselage engineering design data unit, or on the nacelle engineering design data unit. Inlet design, including spike, ramp, mechanisms, etc., shall be shown. Structural details of fixed and removable air filtration systems and inlet and exhaust infrared signature control devices shall be included.

g. Alighting gear – Main, nose, or tail, and auxiliary gear views shall detail the gear structure, rolling stock, retracting mechanism, attachment fittings, catapult, and arrest structure. Sizes and dimensions shall be included for the rolling stock, oleo, travel, wheel travel (where different from oleo travel), and strut length from axle to centerline trunnion.

3.1.2.3 <u>Propulsion System Engineering Design Data.</u> Data shall include the following:

3.1.2.3.1 <u>Engine(s).</u> Views showing location and shape, mounts, access provisions, intake attachment station, etc., unless shown on fuselage or nacelle structural engineering design data. Bleed or bypass ducts not shown on a basic air induction engineering design data. Condition Based Maintenance (CBM) / Health and Usage Monitoring Systems (HUMS) sensor locations.

3.1.2.3.2 <u>Electrical drive motor(s).</u> View showing location and shape, mounts, wiring connections, access provisions.

3.1.2.3.3 <u>Fuel system.</u>

a. View showing tank location(s), capacities, and shape(s), as well as location of the major distribution system components.

b. Views showing MFOD quantity and defining aircraft hover/landing maneuver attitude(s) for each tank.

3.1.2.3.4 Electrical drive system. Views showing generators; battery location(s), capacities, and shapes; the location of the major distribution system components; and motors.

3.1.2.3.5 Drive system.

3.1.2.3.5.1 Schematics. A schematic representation of the complete drive system and mounting configuration on aircraft shall include:

a. Gear boxes and supports. Each gear box shall include representations for gears, bearings, shafts, housings, and supporting structure.

b. Drive shafts and supports. Interconnecting shafting shall be shown with representations for bearings and flexible couplings.

c. Any other rotating elements (e.g., bearings, cooling fans, etc.).

d. CBM/HUMS sensor locations, from the point(s) where the engine output shaft(s) connect to the drive system, to the point(s) of final drive output.

3.1.2.3.5.2 Tabular data. Drive system data shall include the following. Tabulated data shall be referenced back to the item shown on the relevant schematic. Nominal and limit values shall be specified for powers, torques, and shaft speeds.

a. Power, torque, shaft speed, gear ratios, and resonant frequencies shall be tabulated for gears, shafts, and housings of the drive system. Component data shall also include CBM/HUMS sensor function, manufacturer, and part number information.

b. Gear boxes and supports. Shaft speed and number of teeth per gear shall be tabulated for each gear. Bearing type, shaft speed, number of rolling elements, diameter of the rolling elements, pitch diameter, contact angle, and which race rotates shall be tabulated for each bearing. Gear and bearing data shall also include manufacturer and part numbers.

c. Drive shafts and supports. Bearing type, shaft speed, number of rolling elements, diameter of the rolling elements, pitch diameter, contact angle, and which race rotates shall be tabulated for each bearing. Bearing data shall also include manufacturer and part numbers.

d. Any other rotating elements. The function of each element, rotational speed, and number of blades (if applicable) shall be tabulated. Bearing type, shaft speed, number of rolling elements, diameter of the rolling elements, pitch diameter, contact angle, and which race rotates shall be tabulated for each bearing. Element data shall also include manufacturer and part numbers.

3.1.2.4 Equipment Engineering Design Data. Data shall include views that include locations of major component, and schematics that show the functional layout of flight control, avionics, mission equipment, CBM/HUMS, data bus(es), hydraulic, pneumatic, electrical, air conditioning, anti-icing, and Aircraft Survivability Equipment (ASE) groups.

3.1.2.5 CAD Models.

3.1.2.5.1 CFD Surface Geometry. Digital 3D shrink-wrap solid models of the wetted outer mold line for the complete air vehicle not including rotor, proprotor, propeller, or fan blades.

3.1.2.5.2 CSM Geometry. Digital CAD models shall include:

a. 3D solid models of all unique rotor, proprotor, propeller, and fan blades, including internal structure, for use in creating finite element method (FEM) meshes for 3D CSM simulations.

b. 3D solid models of rotor hub components, including internal structure, for use in creating FEM meshes for 3D CSM simulations.

c. Two-dimensional (2D) models of the rotor blade cross-sections, including internal structure, for use in 2D sectional CSM analyses to calculate equivalent-beam properties.

3.1.3 Production Level. The Production Level subdivision is defined IAW MIL-STD-31000 as the procurement or production of an air vehicle for operational testing and fielding. Data shall include design maturity updates to Conceptual Level and Developmental Level data items.

3.2 Rotor/Proprotor/Propeller/Fan Subsystem Aeromechanics Data. Data shall describe the rotor/proprotor/propeller/fan systems, and be divided into two categories: 1) Information that describes the total system, and 2) those properties that vary with blade radius. Radially-varying properties shall be described through plots and tables. Breakpoints for piecewise-linear sections shall be marked. Description of radially-varying properties shall progress outwards from the center of rotation to the blade tip. Three values of collective pitch (minimum, middle and maximum) shall be included to describe properties that vary with blade collective pitch. Properties that vary with operating mode (e.g., hover, cruise, climb/descent) shall be documented for each operating mode. Data shall be included for each unique system.

3.2.1 Conceptual Level.

3.2.1.1 Commercial Item/Non-Developmental Item (CI/NDI) Propellers and Thrust-Producing Fans. The following data shall be provided for third-party off-the-shelf propellers and thrust-producing fans that are to be installed onto the air vehicle without modification.

3.2.1.1.1 Design Description. Data shall include the Table IV data elements for each unique CI/NDI propeller and fan.

Table IV. CI/NDI Propeller and Thrust-Producing Fan Design Data (Conceptual Level)

DATA ELEMENTS
Manufacturer
Model nomenclature
Number of blades
Direction of rotation (observed from front/top of aircraft)
Propeller/fan diameter
Tip clearance for ducted/shrouded propellers/fans
Activity factor per blade
Integrated design lift coefficient, C_{Li}, per blade
Rotational speed
Maximum continuous
Takeoff
Normal
Cruise
Flight idle
Ground idle
Shaft power
Maximum continuous
Takeoff
Blade pitch (fixed or variable?)
Operating pitch range (75% of propeller/fan radius)
Feathered blade pitch (75% of propeller/fan radius)
Polar moment of inertia

3.2.1.1.2 Aerodynamic Performance. CI/NDI propeller and fan performance data shall include either a Propeller Efficiency Chart or a Propeller Efficiency Table.

The performance data shall present propeller efficiency factor, η_p, as the dependent variable of independent variables standard nondimensional propeller power coefficient, C_P, and standard nondimensional propeller advance ratio, J. The ranges of power coefficient and advance ratio shall cover the intended allowable operational envelope of the air vehicle.

3.2.1.2 Rotor System. Data for each rotor, proprotor, propeller, and fan blade shall include the items listed in Table V. Inapplicable data items shall be omitted for developmental propeller and fan characteristics.

Table V. Rotor System Data (Conceptual Level)

DATA ELEMENTS
A brief description of the rotor system including hub type, arrangement of blades, and hinge and bearing configuration
Direction of rotor rotation
Nominal rotational speed(s)
Number of blades
Rotor radius
Root cutout radius
Radius of rotor hub cap ('beanie')/propeller spinner/rotor fairing
Height of rotor hub cap ('beanie')/propeller spinner/rotor fairing
Blade tip clearance for ducted/shrouded rotors/propellers/fans (if applicable)
Chord (specify effective value if chord is not constant)
Geometric-, thrust-, and torque-weighted solidities
Precone, prelag, sweep, and dihedral/anhedral angles
Locations at which precone, prelag, sweep, and dihedral/anhedral start
Thickness (effective if not constant)
Airfoil section (effective if not constant)
Twist angle of the aerodynamic reference line of the section, root to tip (Positive nose up, Twist value at the 75% rotor radius location defined as 0°. If blade twist is non-linear, then specify its linear equivalent.)
Equivalent flywheel polar moment of inertia of the rotor system for capacitance of rotational kinetic energy
Blade mass per blade (outboard of physical or equivalent flapping hinge)
First mass moment of flapping inertia (about physical or equivalent flapping hinge)
Second mass moment of flapping inertia (about physical or equivalent flapping hinge)
Lock number for the ISA SLS atmospheric condition.
Equivalent flapping and lead-lag spring stiffness (hingeless rotor)
Flapping and lead-lag hinge offsets (articulated rotor)
Undersling (teetering or gimbaled rotor)
Pitch bearing offset
Equivalent flapping and lead-lag hinge offsets (hingeless rotor)

First flap and lag natural frequencies
Normal design rotor speed, power-on and power-off. (Data shall include a table of values if design rotor speed is a function of shaft tilt or flight condition).
Hub radius (distance from hub center to blade attachment point)
Projected frontal area of exposed hub, shaft and control rods
Equivalent flat plate drag area of exposed hub, shaft, and control rods (omit if tilting mass drag is described per below)
Equivalent flat plate drag areas of rotor hub cap ('beanie')/propeller spinner/rotor fairing (omit if tilting mass drag is described per below)
Longitudinal rotor shaft tilt* (positive forward, show operating range if variable; data shall include a table of values if shaft tilt is a function of flight condition)
Lateral mass tilt* (positive starboard)
Shaft length from tilt axis to rotor
Location of shaft tilt axis (SL, BL, WL)
Distance from shaft tilt axis to nacelle aerodynamic center
Tilting mass CG location (SL, BL, WL)
Tilting mass weight
Equivalent flat plate drag area of tilting components: VTOL mode Cruise mode
Azimuthal-angle relationship between different rotors ($\psi_{i>1}$[1] when ψ_1[2] = 0, positive in the counterclockwise direction)

*Quantities associated with shaft tilt shall be given in terms of a schedule of values as a function of tilt angle.

[1] $\psi_{i>1}$: Indexing azimuthal angle of the i^{th} rotor when rotor 1's azimuthal angle is set equal to zero.

[2] ψ_1: Index azimuthal angle for rotor 1.

3.2.1.3 Radial Distribution of Blade Properties. Data shall consist of the data included in Table VI for developmental articles. Items shall be omitted if invariant with radial location.

Table VI. Radial Distribution of Blade Properties (Conceptual Level)

DATA ELEMENTS
Blade chord
Blade twist (positive nose up, specified as 0° at the 75% radius spanwise station)
Blade in-plane quarter-chord translation (positive in the direction of rotation)
Blade out-of-plane quarter-chord translation (positive in the direction of thrust)
Airfoil section distribution

3.2.2 Developmental Level. Data shall include design maturity updates to Conceptual Level data items in addition to the following items:

3.2.2.1 Rotor Subsystem. Data shall include the data listed in Table VII. The rotor subsystem data shall represent an accurate and consistent mathematical model of the design.

Table VII. Rotor System Data (Developmental Level)

DATA ELEMENTS
Flapping spring stiffness (where applicable)
Hub spring stiffness (where applicable)
Equivalent flapping and lead-lag spring stiffness (where applicable)
Pitch-flap coupling angle δ_3, (positive when upwards flapping yields a nose-down pitch)
Swashplate/Control Phase angle
Flapping and lead-lag damping (where applicable)
Longitudinal and lateral gimbal damping
Control system stiffness (collective, cyclic, rotating)
Control system damping (collective, cyclic, rotating)

3.2.2.2 Rotor Blade Engineering Design Data. Data shall include separate views of each unique rotor blade.

3.2.2.2.1 Locations and Dimensions. Views shall clearly note the following items in the relevant engineering design data:

a. Value(s) of planform chord and twist.

b. Spanwise distribution of designated airfoil sections, with transition zones clearly demarcated.

c. Orientation of the designated airfoil section(s) with respect to (WRT) the rotor blade's spanwise axis shall be clearly marked to identify local angular rotations and linear translations required to define the geometric surface topology.

d. The geometric treatment of surface topology transitions (flat-wrap, linear interpolation, etc.) between designated airfoil profiles shall be documented. ((See Raymer, D. P., Aircraft Design, a Conceptual Approach, 5th ed., 2012, pp. 171-205 for additional details.) (Copies can be obtained from: AIAA, 12700 Sunrise Valley Dr., Ste 200, Reston, VA 20191-5807.))

3.2.2.3 Rotor Hub.

3.2.2.3.1 Engineering Design Data. Data for each unique rotor hub region shall include views that define hub, blade, and control kinematic movement. The views shall include the following items:

a. A vertical, longitudinal, and lateral reference axis system with respect to the fuselage.

b. The location of the axis of rotation for each hinge (actual or equivalent for rigid rotors), and the angle between the hinge-rotation axis and the reference axes.

c. The angular range of rotation about each hinge axis (actual or equivalent for rigid rotors), and the angular location of blade-motion stops (as applicable).

d. Both rotating and nonrotating swashplates, shown perpendicular to the shaft (if applicable).

e. The location of the centerline of each control link above the rotating swashplate, the length of each control link, and the angle between each control link and the reference axes (if applicable).

f. The orientation of the blade's spanwise axis with respect to the reference axes (i.e., rotor blade droop, sweep, coning, pretwist, etc.)

g. The location and orientation of all tension/compression and torsion spring and damper forces and torques.

h. The location of all mechanical coupling points and the line of action of all forces through them.

i. All rotor blade or hub mounted vibration reduction device envelop and mounting interface definitions.

3.2.2.3.2 Tabular Data. Tables shall include mass, moments of inertia, and stiffness and damping values for the following items. Stiffness and damping data shall include both tension/compression and torsion components. Data for all six translational and angular degrees of freedom shall be included for each item.

a. Each hinge, coupling, joint, shank, shaft, bearing, and any other mechanical components within the rotor hub. (Equivalent hinges for rigid rotors.)

b. Each control system component, up to and including blade servo-flaps.

c. Each blade-mounted passive vibration-reduction device.

3.2.2.3.3 Graphical Data. Data shall include the following plots. Blade deflection limits/stops shall be demarcated on each plot.

a. Position displacement as a function of blade coning/flapping and lead-lag angular deflections for each spring and damper, including both tension/compression and torsion components.

b. Tension/compression spring and damper forces as a function of blade flap-wise and lead-lag-wise angular deflections for a representative selection of rotor speeds for each nonlinear damper.

c. Torsion spring and damper torques versus blade flap-wise and lead-lag-wise angular deflections for a representative selection of rotor speeds for each nonlinear damper.

3.2.2.4 Radial Distribution of Blade Properties. Data shall include planform views that show radial variation of CG, aerodynamic reference point, shear center, tension center, pitch axis, and elastic axis. This data plus the data in Table VIII shall be documented in tables. The contractor shall describe the blade axis coordinate system. All parameters shall be measured with respect to this coordinate system.

Table VIII. Radial Distribution of Rotor Blade Properties (Developmental Level)

DATA ELEMENTS
Coordinates for pitch axis
Geometric twist
Aerodynamic twist (if different from geometric twist)
Airfoil section designation
Airfoil thickness ratio
Coordinates for sectional aerodynamic center
Cross-sectional area
Blade sectional running weight
Coordinates for sectional center of mass
Coordinates for principal axes (based on mass)
Chordwise bending stiffness
Flapwise bending stiffness
Torsional stiffness
Coordinates for chordwise and flapwise shear center
Chordwise mass moment of inertia
Flapwise mass moment of inertia
Mass moment of inertia about elastic axis
Section polar radius of gyration (mass) about elastic axis
Coordinates for tension axis

3.2.2.5 Blade Dynamic and Aeroelastic Modal Data.

a. Southwell (fan) plots of blade resonant frequencies for fully-coupled modes showing the lowest $4N_b$ per revolution frequencies, including the effect of collective pitch. (N_b is defined as the number of blades per rotor). Rotor speeds shall include 0 r/min (for natural frequencies) through the maximum overspeed condition of the drive train.

b. Mode shapes at design and power-on rotor rotational speed(s) for the modes identified in 3.2.2.5(a.) above shall be plotted to show edgewise, flapwise, and torsional displacements for each mode shape. Descriptions shall include the method and assumed hub boundary conditions used in calculating these mode shapes.

c. Mode shapes at minimum and maximum power-on and power-off rotor rotational speeds for the modes identified in 3.2.2.5(a.) above shall be plotted to show edgewise, flapwise, and torsional displacements for each mode shape. Descriptions shall include the method and assumed hub boundary conditions used in calculating these mode shapes.

3.2.2.6 Rotor Subsystem Material Data. Data shall include details on materials used in the rotor blade and hub components for 3D CSM analysis using the FEM, and 2D cross-sectional analysis in conjunction with the data described in 3.1.2.5.2 above.

3.2.2.7 Rotor Blade Track and Balance. Data shall include the data described in Table IX.

Table IX. Rotor Blade Track and Balance

DATA ELEMENTS
Rotor blade target span moment about the rotor's center of rotation with factory & field tolerances
Rotor blade adjustable span weight location (spanwise station)
Rotor blade adjustable chord weight location (spanwise station)
Rotor blade adjustable chord weight location (chordwise station)
Rotor blade adjustable span weight(s) (weight of each adjustable weight and maximum allowed)
Rotor blade adjustable chord weight(s) (weight of each adjustable weight and maximum allowed)
All information necessary to adjust weights (e.g. weight bolt/nut torques, cover plate torques, etc.)

3.2.2.8 Ground Resonance Model. Data shall include items IAW Table X for the range of potential ground operating conditions. Data shall include vehicle inertia and main rotor speed for conditions of alighting-gear unloading of 0 to 99.99 percent airborne, in increments of 20 percent gear unloading. Definitions and discussion of these data shall be IAW National Advisory Committee for Aeronautics (NACA) Technical Report NACA-TR-1351 (Copies of this NACA reference are available from www.ntrs.nasa.gov). Blade damper properties shall be described over the allowable operational range of temperatures, frequencies, and amplitudes. Effective hub parameters shall be included for body modes with the largest structurally-significant resonant amplitudes.

Data shall also include plots of tire/oleo stiffness and damping versus load.

Table X. Data for Ground Resonance Model

DATA ELEMENTS
Effective blade lag damper viscous damping rate
Effective blade lag damper spring rate
Effective hub viscous damping in the longitudinal direction
Effective hub viscous damping in the lateral direction
Effective hub stiffness in the longitudinal direction
Effective hub stiffness in the lateral direction
Effective hub mass in the longitudinal direction
Effective hub mass in the lateral direction
Lag hinge offset
First mass moment of blade about lag hinge
Second mass moment of blade about lag hinge
Blade mass (outboard of lag hinge)

3.2.3 Production Level. Data shall include design maturity updates to Conceptual Level and Developmental Level data items.

3.3 Fixed Aerodynamic Surface Aeromechanics Data. Data for each non-rotating aerodynamic surface shall include the following.

3.3.1 Conceptual Level.

3.3.1.1 Geometry. Data for each fixed aerodynamic surface (excluding rotor blades) shall include the items in Table XI.

Table XI. Fixed Aerodynamic Surface Geometric Data

DATA ELEMENTS
Planform area (theoretical and wetted)
Span
Aspect ratio (theoretical)
Chord (tip and theoretical root)
Sweep angle of quarter chord
Orientation WRT fuselage reference axis system
Thickness (tip and root)
Airfoil section designation(s)
Control surface, flap or leading edge device area
Control surface, flap or leading edge device span
Control surface, flap or leading edge device chord

3.3.1.2 Aerodynamics. Data for each fixed aerodynamic surface (excluding rotor blades) shall include the items in in Table XII.

Table XII. Fixed aerodynamic surface Force and Moment Data

DATA ELEMENTS
Surface lift curve slope at zero lift
Surface drag coefficient at zero lift
Surface pitching moment coefficient at zero lift
Maximum lift coefficient
Maximum lift-to-drag value
Oswald wingspan aerodynamic efficiency factor

3.3.2 Developmental Level. Data shall include design maturity updates to Conceptual Level data items, in addition to the following items:

3.3.2.1 Engineering Design Data. Data shall include views showing separate planform layout for each unique fixed aerodynamic surface.

3.3.2.1.1 Locations and Dimensions. The following items shall be clearly annotated on the appropriate views:

a. Value(s) of planform chord, twist, sweep, dihedral/anhedral, and the spanwise distribution of designated airfoil sections.

b. Orientation of the designated airfoil section(s) WRT the fixed aerodynamic surface's spanwise-axis shall be clearly demarcated to identify local angular rotations and linear translations required to define the geometric surface topology.

c. Spanwise distribution of designated airfoil sections, with transition zones clearly demarcated.

d. The geometric treatment of surface topology transitions (flat-wrap, linear interpolation, etc.) between designated airfoil profiles shall be documented. (See Raymer, D. P., Aircraft Design, A Conceptual Approach, 5th ed., 2012, pp. 171-205, for additional detail.)

e. Spanwise variation in airfoil section aerodynamic reference point.

f. Spanwise variation in airfoil section center of mass.

g. Spanwise variation in the elastic axis.

h. Spanwise variation in the tension center (neutral axis).

3.3.2.2 Spanwise Distribution of Properties. Aerodynamic and structural dynamics data shall consist of the data required by Table XIII. The contractor shall describe the blade axis coordinate system. All parameters shall be measured with respect to this blade axis coordinate system.

Table XIII. Spanwise Distribution of Fixed aerodynamic surface Properties.

DATA ELEMENTS
Coordinates for pitch axis (moving surface)
Geometric twist
Aerodynamic twist (if different from geometric twist)
Airfoil section designation
Airfoil thickness ratio as percentage of chord length
Coordinates for sectional aerodynamic center
Airfoil cross-sectional area
Fixed aerodynamic surface running weight
Coordinates for sectional center of mass
Coordinates for principal axes (based on mass)
Chordwise bending stiffness
Flatwise bending stiffness
Torsional stiffness
Coordinates for chordwise and flatwise shear center
Chordwise mass moment of inertia
Flatwise mass moment of inertia
Mass moment of inertia about elastic axis
Section polar radius of gyration (mass) about elastic axis
Coordinates for tension axis

3.3.2.3 Aerodynamics. The 3D lift, drag, and pitching moment coefficients (as a function of angle of attack and control surface (flap, aileron, slat, etc.) position) of each of the fixed aerodynamic surfaces shall be documented to include stall and any reasonable area of negative angle of attack operation of the surface (e.g., download in hover, vertical flight, etc.).

3.3.2.4 Control Surface Description. Data for each control surface shall include items as specified in Table XIV:

Table XIV. Data for Control Surfaces

DATA ELEMENTS
Linear spring rate, including actuator and moving surface
Polar moment of inertial of control surface mass about the hinge line axis
Location of the control surface center of mass WRT the hinge line axis. (positive direction is from the hinge line axis to control surface aerodynamic center of pressure)
Location of static balance weight(s) WRT the hinge line axis. (positive direction is from the hinge line axis to control surface aerodynamic center of pressure)
Mass of static balance weight(s)
Location of dynamic balance weight(s) WRT the hinge line axis. (positive direction is from the hinge line axis to control surface aerodynamic center of pressure)
Mass of dynamic balance weight(s)
Control surface adjustable chord weight location (span location)
Control surface adjustable chord weight location (chord station)
Control surface adjustable chord weight(s) (weight of each adjustable weight and maximum allowed)
All information necessary to adjust weights (e.g. weight bolt/nut torques, cover plate torques, etc.)

3.3.2.5 Dynamic and Aeroelastic Modal Data. Data shall include the following:

a. Natural frequencies and generalized modal masses for structurally significant modes shall be tabulated. The associated mode shapes shall be plotted to show edgewise, flatwise, and torsional displacements of each mode shape. Documentation shall include a complete description of the method used, including all assumed boundary conditions, in calculating the mode shapes.

b. Damping coefficient and variation in frequency of each mode versus rotor speed and equivalent air speed shall be plotted.

c. Outputs from dynamic and aeroservoelastic analyses, including root locus plots, Bode plots, Nyquist plots, or other stability presentation forms.

3.3.3 Production Level. Data shall include design maturity updates to Conceptual Level and Developmental Level data items.

3.4 Airfoil Aerodynamics.

3.4.1 Conceptual Level.

3.4.1.1 Aerodynamic Properties. Data at the Conceptual Level shall include conceptual design surrogate models of the sectional C_l, C_d, and C_m

characteristics of each airfoil section as a function of *Ma* and Reynolds number, *Re*, in graphic or tabular form. The maximum Mach number (Ma_{max}) for each airfoil section shall be determined by considering the specific application (e.g., rotor blade tip versus root, fixed aerodynamic surface, low speed (incompressible) aerodynamic environment, etc.). The minimum and maximum Reynolds number limits, (Re_{min} and Re_{max}, respectively) shall be based on the application(s) and the aerodynamic characteristics of the airfoil section (e.g., laminar flow airfoil, drag or stall characteristics significantly influenced by laminar-turbulent transition or shock-induced transition, small vehicle size, etc.) The range of α shall be prescribed by the application (e.g., 180° to +180° for regions of a rotor blade that experience reverse flow, or a wing that is subject to rotor downwash impingement; -20° to +20° for a tail surface not subject to rotor wake impingement, or a conventional fixed-wing aircraft; etc.) Coefficient C_m shall be referenced to the quarter chord location aft of the airfoil's leading edge. The surrogate models shall quantitatively describe the following relationships:

a. C_l vs α for Ma = 0 to Ma_{max} and $Re = Re_{min}$ to Re_{max}

b. C_d vs α for Ma = 0 to Ma_{max} and $Re = Re_{min}$ to Re_{max}

c. C_m vs. α for Ma = 0 to Ma_{max} and $Re = Re_{min}$ to Re_{max}

d. C_d vs. c_l for Ma = 0 to Ma_{max} and $Re = Re_{min}$ to Re_{max}

e. C_m vs. c_l for Ma = 0 to Ma_{max} and $Re = Re_{min}$ to Re_{max}

3.4.1.1.1 Discussion. A narrative describing the conceptual design airfoil model shall be included, including the data basis for the model. The procedure by which the model was derived from the data basis shall be described. Details of any adjustments or optimizations made to the model in relation to the data basis shall be described.

3.4.2 Developmental Level. Data shall include design maturity updates to Conceptual Level data items in addition to the following items:

3.4.2.1 Engineering Design Data. Data shall include views of each airfoil section used on the air vehicle IAW 2.7.1 above. The following items shall be shown on each view:

a. Camber line.

b. Chord line.

c. Aerodynamic center (Any range of variation shall be demarcated, if applicable).

d. Center of sectional mass.

e. Tension center (neutral axis).

f. Shear center (flexural center).

g. Torsion center.

h. Elastic center.

i. Trailing-edge reflex angle.

j. Trailing-edge trim tab deflection angle.

k. Trailing-edge trim wedge angle.

3.4.2.2 Airfoil Section 2D CAD. 2D CAD shrink-wrap models of each airfoil section used on the air vehicle IAW 2.7.2 shall be included in the report.

3.4.2.3 Aerodynamics. Coefficients C_l, C_d, and C_m of each airfoil section as a function of *Ma* and *Re* shall be described in graphic and tabular form. The data shall be representative of airfoil force and moment coefficients for two-dimensional flow at aerodynamic full-scale. Ma_{max} for each airfoil section shall be determined by considering the specific application (e.g., rotor blade tip versus root, fixed aerodynamic surface, low speed (incompressible) aerodynamic environment, etc.). Re_{min} and Re_{max} shall be based on the application(s) and the aerodynamic characteristics of the airfoil section (e.g., laminar flow airfoil, drag or stall characteristics significantly influenced by laminar-turbulent transition or shock-induced transition, small vehicle size, etc.) α shall be prescribed by the application (e.g., 180° to +180° for regions of a rotor blade that experience reverse flow, or a wing that is subject to rotor downwash impingement; -20° to +20° for a tail surface not subject to rotor wake impingement, or a conventional fixed-wing aircraft; etc.) Coefficient C_m shall be referenced to the quarter chord location aft of the airfoil's leading edge. The plots and tables should describe the following relationships:

a. C_l vs. α for representative values of *Ma* and *Re*,

b. C_d vs. α for representative values of *Ma* and *Re*,

c. C_m vs. α for representative values of *Ma* and *Re*,

d. C_l vs. *Ma* and *Re* for representative values of α,

e. C_d vs. *Ma* and *Re* for representative values of α,

f. C_m vs. *Ma* and *Re* for representative values of α,

g. C_d vs. C_l for representative values of *Ma* and *Re*, and

h. C_m vs. C_l for representative values of *Ma* and *Re*.

3.4.2.3.1 Discussion. A complete description of the source of the data, including a description of any adjustments, shall be included. The procedure by which the data are obtained shall be described. Corrections shall include adjustments to data to account for *Re* effects such as geometrical scale differences, surface roughness, laminar-turbulent flow transition location and behavior; corrections for wind tunnel effects such as wall corrections; etc.

3.4.3 Production Level. Data shall include design maturity updates to Conceptual Level and Developmental Level data items.

3.5 Airframe Aeromechanics. Data shall include the following for all normal modes of flight. The data shall be documented in the wind-axis coordinate system. The wind-axis coordinate system and force and moment sign conventions shall be described WRT the aircraft coordinate system. Coordinates for aerodynamic reference point(s) (point(s) at which aerodynamic forces and moments are defined to be acting) shall be documented. A complete description of the source of the data, including a description of any adjustments, shall be included. The procedure by which the data are obtained shall be described. Corrections shall include adjustments to data to account for *Re* effects such as geometrical scale differences, surface roughness, laminar-turbulent flow transition location and behavior; corrections for wind tunnel effects such as wall corrections; etc.

3.5.1 Conceptual Level.

3.5.1.1 Fuselage Aerodynamics. Data shall include items IAW Table XV. For the purposes of this paragraph, the fuselage shall be defined in such a way as to exclude all items in 3.2 and 3.3 above. The characteristic dynamic pressures, areas, and length scales used for nondimensionalization shall be documented.

Table XV. Fuselage Aerodynamic Data

DATA ELEMENTS
α_W[1] for C_L[2] = 0 at β_W[3] = 0º (i.e., zero lift angle-of-attack)
Maximum C_L at $\beta_W = 0º$
α_W for maximum C_L at $\beta_W = 0º$
∂[4]$C_L/\partial\alpha_W$ at $\beta_W = 0º$ (i.e., equivalent lift-curve slope)
$\partial C_L/\partial\beta_W$ at $\alpha_W = 0º$
β_W for which $C_L = 0$ at $\alpha_W = 0º$
Minimum C_D[5] at $\beta_W = 0º$
α_W for minimum C_D at $\beta_W = 0º$
$\partial C_D/\partial\alpha_W$ at $\beta_W = 0º$
$\partial^2 C_D/\partial\alpha_W^2$ at $\beta_W = 0º$
β_W for which C_Y[6] = 0 at $\alpha_W = 0º$
β_W for which $\partial C_Y/\partial\beta_W = 0$ at $\alpha_W = 0º$
C_Y for which $\partial C_Y/\partial\beta_W = 0$ at $\alpha_W = 0º$
C_m[7] at $\alpha_W = 0º$ and $\beta_W = 0º$
$\partial C_m/\partial\alpha_W$ at $\beta_W = 0º$ (i.e., static longitudinal stability)
α_W for which $C_m = 0$ at $\beta_W = 0º$
C_l[8] at $\alpha_W = 0º$ and $\beta_W = 0º$
$\partial C_l/\partial\beta_W$ at $\alpha_W = 0º$ (i.e., static lateral stability)
C_n[9] at $\alpha_W = 0º$ and $\beta_W = 0º$
$\partial C_n/\partial\beta_W$ at $\alpha_W = 0º$ (i.e., static directional (weathercock) stability)
β_W for which $C_n = 0$ at $\alpha_W = 0º$
C_D at $\alpha_W = -90º$ and $\beta_W = 0º$ (i.e., hover download coefficient)
Aircraft SL, BL, and WL coordinates of the fuselage's aerodynamic center of pressure

[1]α_W: Fuselage pitch angle-of-attack in the wind-axis coordinate system.
[2]C_L: Fuselage 3D nondimensional aerodynamic lift force.
[3]β_W: Fuselage yaw angle-of-attack in the wind-axis coordinate system.
[4]∂: Mathematical symbol for partial derivative.
[5]C_D: Fuselage 3D nondimensional aerodynamic drag force.
[6]C_Y: Fuselage 3D nondimensional aerodynamic side force.
[7]C_m : Fuselage 3D nondimensional aerodynamic pitching moment.
[8]C_l: Fuselage 3D nondimensional aerodynamic rolling moment.
[9]C_n: Fuselage 3D nondimensional aerodynamic yawing moment.

3.5.1.2 <u>Drag Buildup.</u> Data shall include analysis of the drag of each component of the airframe from both the downward vertical direction for hover and vertical flight calculations, and from the longitudinal and lateral directions for yaw angles of 0° (forward flight), ±90° (sideward flight), and 180° (rearward flight). For purposes of this data, a component shall be any item on the air vehicle which contributes more than two percent of the total drag or that cannot be conveniently combined with another item. Drag from excrescences, surface roughness, leakage, interference, and scrubbing shall be included as separate items. Tabulated data shall include a list of the drag items, horizontal and vertical 3D nondimensional drag coefficients, C_D, horizontal and vertical equivalent flat plate drag areas, and a description of the source of the drag estimate. The characteristic dynamic pressures and areas used for nondimensionaliztion of forces and calculation of equivalent flat plate drag areas shall be documented. Drag values shall not incorporate effects of rotor/propeller thrust recovery. Rotor/propeller thrust recovery factors used in performance calculations shall be itemized separately. Documentation shall include a description of the wake model used to substantiate interference predictions. A low-fidelity approximation of rotor wake velocities can be calculated by vector addition of twice the rotor's induced-inflow velocity from momentum theory and the freestream velocity. More sophisticated wake models may be used for interference calculations for increased fidelity.

3.5.2 Developmental Level. Data shall include design maturity updates to Conceptual Level data items in addition to the following items:

3.5.2.1 Airframe Aerodynamics. Data shall include nondimensionalized aerodynamic forces and moments generated by the entire airframe (both excluding and including fixed aerodynamic surfaces) in graphic and tabular form. The characteristic dynamic pressure and length scales used in the nondimensionaliztion shall be described. The force and moment data shall include a matrix of yaw and pitch angles with a range to sufficiently cover the expected flight envelope that includes rotor/propeller wash aerodynamic interactions. The numerical methodology to be used to interpolate between data points shall be specified and described by the contractor. Drag values shall not incorporate effects of rotor/propeller thrust recovery. Rotor/propeller thrust recovery factors used in performance calculations shall be itemized separately. Documentation shall include a description of the rotor wake model used to substantiate interference predictions. A low-fidelity approximation of rotor wake velocities can be calculated by vector addition of twice the rotor's induced-inflow velocity from momentum theory and the freestream velocity. More sophisticated wake models may be used for interference calculations for increased fidelity.

3.5.2.2 Component Aerodynamics. Data shall include airframe nondimensionized aerodynamic forces and moments generated with each of the major components removed separately, in graphic and tabular format. The characteristic dynamic pressure and length scales used in the nondimensionaliztion shall be described. The categorization of "major components" is left to the discretion of the contractor. Items typically tested in a component buildup (e.g., fuselage, wings, stores, alighting gear, stabilizing surfaces) shall be sufficient for characterization. The force and moment data shall include a matrix of yaw and pitch angles with a range to sufficiently cover the expected flight envelope that includes rotor/propeller wash aerodynamic interactions. The numerical methodology to be used to interpolate between data points shall be specified and described by the contractor. Drag values shall not incorporate effects of rotor/propeller thrust recovery. Rotor/propeller thrust recovery factors used in performance calculations shall be itemized separately. Documentation shall include a description of the wake model used to substantiate interference predictions. A low-fidelity approximation of rotor wake velocities can be calculated by vector addition of twice the rotor's induced-inflow velocity from momentum theory and the freestream velocity. More sophisticated wake models may be used for interference calculations for increased fidelity.

3.5.2.3 Airframe Structural Dynamics. Data shall include a description of the airframe structure. The operational configuration, weight, and loading shall be for the Primary Mission as specified in the contract.

3.5.2.3.1 FEM Model. Data shall include a FEM model of the aircraft airframe. Documentation shall include the following items associated with the model:

a. Engineering design data views of the model, including elements representing the fuselage, rotor pylons, empennage, wings, store support pylons, and stores, as applicable to the design.

b. SL, BL, and WL coordinates for each node of each element.

c. Mass and stiffness properties of each FEM element.

d. Euler angle orientation of each FEM element.

3.5.2.3.2 Dynamic and Aeroelastic Modal Data. Data shall include a detailed FEM model of the airframe (including any fixed aerodynamic surfaces such as wings and stabilizers). Data shall also include all information required to replicate the following modal data:

a. Generalized masses, frequencies, and damping of each airframe mode up to $4N_b$ per revolution.

b. Modal displacements at each rotor hub employing six degrees of freedom at each mode (linear translations and angular rotations in a Cartesian coordinate system).

c. Modal displacements at the following locations on the airframe:

1) Pilot and co-pilot positions.

2) Stores stations.

3) Points at which wing stabilizing surfaces and store support pylons are attached.

4) Points at which vibration absorbers and isolation devices are attached.

5) Points at which narrow field of regard sensor and illumination devices are attached.

6) Selected points at which specified forces may act (for example, forces to be used to simulate shake test or for other known excitations).

3.5.2.4 Airframe-Mounted Absorbers and Isolators. Data shall include the following data for airframe-mounted absorbers and isolators:

a. The stiffness, mass, and damping properties for vibration devices such as airframe-mounted absorbers, isolators and hub-mounted absorbers.

b. The SL, BL, and WL coordinates for the points of connection of vibration devices to the airframe.

c. Engineering design data views that clearly define the specific configuration and installation of all vibration absorption and isolation devices.

3.5.3 Production Level. Data shall include design maturity updates to Conceptual Level and Developmental Level data items.

3.6 Control Subsystem.

3.6.1 Conceptual Level.

3.6.1.1 General Design. Data shall include a general description of the flight control system (FCS) concept (e.g., digital optical, electrical (digital and/or analog), mechanical, hydraulic, pneumatic). The description shall include details of the various modes of operation and the theory of operation. The description shall include details of any unusual or difficult design features and problems. The description of stability augmentation systems (SAS) and stability augmentation control systems (SCAS) shall include the type of system (e.g. fly-by-wire, fly-by-light, electrical, mechanical), type of augmentation (e.g. electronic, fluidic, hybrid), augmentation modes, anticipated redundancy, control authority limits, sensors, servos, and rotor and control surface implementation(s).

3.6.2 Developmental Level. Data shall include design maturity updates to Conceptual Level data items in addition to the following items:

3.6.2.1 Control Travel. Data for control travel and sign convention IAW Table XVI shall be included. Contractor Furnished Information (CFI) is used here for situations where units are design dependent. Equivalent quantities may be required for applications such as the flight controls for an unmanned air vehicle (UAV) that does not use sticks, pedals, levers, etc.

(NOTE: Rotor blade feathering angles are defined as $\theta_f = \theta_0 - \theta_{1c} \cos \psi - \theta_{1s} \sin \psi$, measured at the 75% rotor radius station of the blade.)

Table XVI. Control Travel Data

DATA ELEMENTS
Minimum and maximum collective pitch blade angle (θ_0) at the 75% rotor-radius-station, per rotor
Minimum and maximum longitudinal cyclic pitch blade angle (θ_{1c}; WRT θ_0) per rotor
Minimum and maximum lateral cyclic pitch blade angle (θ_{1s}; WRT θ_0) per rotor
Maximum collective stick position (positive for increasing thrust; minimum thrust is defined as 0 inches)
Minimum and maximum longitudinal cyclic stick position (positive for forward thrust) *
Minimum and maximum lateral cyclic stick position (positive for rightward thrust)*
Minimum and maximum pedal position (positive for rightward rotation of the vehicle nose) *
Minimum and maximum control surface positions (rudder, elevator, flap, aileron, slats, etc., as applicable)
Minimum and maximum control surface control positions
Minimum and maximum rotor-shaft tilt angle
Minimum and maximum rotor-shaft tilt control position
Minimum and maximum wing variable incidence angle
Minimum and maximum wing variable incidence control potion
Minimum and maximum variable speed engine speed
Minimum and maximum engine speed control position
Minimum and maximum variable speed transmission gear stepping
Minimum and maximum variable speed transmission gear control position
Minimum and maximum boost/ Automatic Flight Control System (AFCS) servo input and output position

*Reference control position is the midpoint of the range. If the longitudinal and lateral cyclic swashplate deflections are not symmetric about the reference control position, the offset shall be included.

3.6.2.2 Control Subsystem Description. The technical description of the total control subsystem shall include the following:

a. Type of system: Linkage description (e.g., digital optical, electrical (digital and/or analog), mechanical, hydraulic, pneumatic), boost system, trim system, backup control system(s), level of augmentation (i.e., SAS, SCAS, etc.), unique or nonstandard features (e.g., control mixing and nonlinearities such as actuator rate, electronic amplifier saturation, and actuator position limits).

b. A description of any interfaces between the flight control computer(s) and control-actuating mechanisms, to include type(s) of data bus(es).

c. A detailed algebraic representation of mechanical control system dynamics, to include mass and stiffness properties and nonlinear effects such as friction and hysteresis.

d. Augmentation system: Axes augmented, type of hardware (mechanical, electrical, fluidic, hybrid), type of augmentation (e.g., rate command, attitude command, use of feed forward and feedback loops), actuator functional installation (e.g., parallel, series), actuator type (e.g., electrical, electro-hydraulic), augmentation modes and the methodology used for activating and selecting (switching) modes, authority limits, sensors.

e. Cockpit/Control station controls: Configuration (e.g., conventional, side-arm), control travels, pilot/operator station arrangement (e.g., side-by-side, tandem, staggered).

f. Method and description of rotor-control mechanization (e.g., Individual Blade Control (IBC), swashplate/swashplate-type (rise-and-fall, collective-sleeve, etc.)).

g. Description of the coupling between rotor-shaft tilt and control inputs (for applicable configurations).

h. Descriptions of any rotor-to-rotor control couplings (e.g., differential cyclic, main-rotor collective to tail-rotor collective).

i. An algebraic/kinematic model of the relationship between the cockpit/control station controls and any fixed aerodynamic surfaces linked to them, along with a brief description of any augmentation systems.

j. Details of inceptor force - displacement and frequency response characteristics for all operational modes of active control inceptors.

3.6.2.2.1 Linkages. Data shall describe control linkages between the cockpit/control-station and the ultimate control-actuating mechanism(s) in each of the following formats:

a. Block diagram(s) to include: cockpit/control-station controls; bungee springs; force-feel systems (including break-out forces and gradients); control system stiffnesses, control mixing; boost/AFCS servos; devices to transfer controls between fixed and rotating systems (e.g., swashplate, electrical slip ring, hydraulic/pneumatic rotary union); rotor-blade-control mechanisms (e.g., pitch link and horn, servo-flap/-tab); fixed-aerodynamic-surface control mechanisms (e.g., flap, aileron, slat, brake, elevator, rudder, stabilator); rotor-shaft tilt mechanisms; engine-nacelle tilt mechanisms; sensors which drive servos; pylon coupling; control inputs from augmentation systems in the rotating frame (e.g., stabilizer bar, control gyro); and non-unity gearing in the control-linkage servos and resulting rotor-blade feathering angles.

b. Algebraic representation of items in the block diagram(s), particularly transfer functions for: control mixing; augmentation systems; control linkages; sensors; servos; non-unity gearing; and stabilization or control augmentation loops.

3.6.2.3 Engine Fuel Control Description. Data that describes the operation of the engine fuel control system shall include:

k. A block diagram of the engine fuel control system, along with an algebraic representation of each component of the system.

l. Definition of partial- or full-authority electronic fuel control shall include a description of input and output interface parameters, control loops (including speed control, feed-forward compensation, and torque output limiting), gains, and time constants.

m. A description of any interfaces between the flight control computer(s) and the engine(s), to include type of data bus(es).

3.6.2.4 AFCS Digital Model. Data as follows shall be included, along with an AFCS algorithmic model:

a. Timing delays due to sensor nonlinearities, management and transfer of sensor data to/from the AFCS, and AFCS computational processing.

b. Interface Definition: A listing of all AFCS input and output parameters, with a description of each parameter’s function, variable type, and engineering units.

c. Data Files: Files with initialization parameters, gains, and time constants that are accessed by the AFCS algorithmic model.

3.6.2.5 Aircraft Configuration/Trim Methodology. Data shall include the following items.

a. A description of any automated aircraft configuration and trim schemes implemented by the control system. This shall include scheduled trim targets, aircraft configuration states (e.g., wing sweep, engine speed scheduling, transmission speed scheduling, rotor tilt scheduling, rotor stop-and-fold, tail-sitter conversion between takeoff, cruise, and alighting modes), control mixing to achieve desired lift and thrust, drag minimization, etc.

b. A general control system layout or series of layouts showing rotors, control surfaces, engine(s), actuation systems, feel systems, pilot's controls, and control panel organization. Illustrations of means of providing redundancy and emergency provisions. Layouts including wiring schematics for all electrical and electronic portions of the FCS, and attendant electrical, hydraulic, and pneumatic power inputs to the FCS. Data bus type(s) shall be identified on the wiring schematics.

c. Block diagrams of the FCS, including: transfer or describing functions; identified normal control paths; redundancy; manual overrides; emergency provisions; and location and type of sensors and control devices used.

d. Mathematical models of the FCS, the unaugmented aircraft, and any other data required to simulate FCS operation during steady and maneuvering flight for calculation of rotor and control surface trim settings, engine shaft speed, rotor shaft speed(s) and tilt(s), jet thrust, and any other design-specific component used to exert control over aircraft flight behavior.

3.6.3 Production Level. Data shall include design maturity updates to Conceptual Level and Developmental Level data items.

3.7 Propulsion and Drive Subsystem.

3.7.1 Conceptual Level.

3.7.1.1 Engine Performance Description. Documentation shall include uninstalled minimum specification engine static performance data IAW 2.15 above.

3.7.1.1.1 Commercial Item/Non-Developmental Item (CI/NDI) Engines. Documentation shall be IAW 3.8.1.3 below for CI/NDI third-party off-the-shelf engine(s) integrated onto the air vehicle.

3.7.1.2 Air Induction and Exhaust System Losses. Data shall include inlet ram pressure recovery efficiency and power losses such as: engine inlet air filtration;

particle separation; and inlet and exhaust infrared and acoustic signature suppression. Documentation shall include detailed descriptions of any variation of losses with air vehicle operating condition if required for flight performance analysis (e.g., selectable particle filter bypass, active signature controls).

3.7.1.3 Drive System Power Take-Off Requirements and Losses. Data shall include descriptions of all power take-off (PTO) requirements and losses occurring between engine output shaft(s) and rotor shaft(s), clearly identified as “generator losses,” “accessory losses,” “drive system losses,” “anti-torque branch losses,” “propulsor branch losses,” and all other significant power sinks as necessary for clarity. Documentation shall include a description of any variation of losses with each associated air vehicle operating condition when necessary for the analysis of air vehicle flight performance.

3.7.1.4 Drive System Shaft Speed Scheduling. Data shall include a description of drive system shaft speed scheduling as a function of flight condition. Documentation shall also include the ratio of speed controlled by variable speed engine(s) versus variable speed transmission(s) as a function of flight condition. Data shall include table(s) of engine and transmission output shaft speed as a function of flight condition.

3.7.2 Developmental Level. Data shall include design maturity updates to Conceptual Level data items in addition to the following items:

3.7.2.1 Engine Performance Description. Data describing engine performance shall include:

a. An engine cycle model that satisfies the documentation requirements of Society of Automotive Engineers, International, Aerospace Standard SAE AS681, Gas Turbine Engine Performance Presentation for Computer Programs. (Copies of this reference are available online from www.sae.org or Society of Automotive Engineers, International, 400 Commonwealth Dr., Warrendale, PA 15086-7511.)

b. A model of the engine electronic fuel controller in electronic format, including: input files of gains; time constants and initialization parameters that are accessed by the model; and a listing of all input and output parameters, with a description of each parameter’s function, variable type and engineering units.

c. A description of engine instrumentation, including measurements of temperatures, pressures, flows, and vibrations.

d. Descriptions of engine inlet temperature rise and engine performance degradation due to hot gas ingestion from: recirculated engine exhaust during hover-in-ground-effect; and rocket and missile launches (single through ripple launches).

3.7.2.2 Engine Thermodynamic Description. Data that describe engine thermodynamic and dynamic responses shall include:

a. A block diagram of engine components (inlet, duct, compressor, combustor, turbine stages, and exhaust), along with an algebraic representation for each component of the block diagram. Documentation shall include one-dimensional thermodynamic equations, tables, or maps used to quantify the quasi-steady flow, pressure, temperature, or power (as appropriate) for each system component. SAE AS755, Aircraft Propulsion System Performance Station Designation, is recommended as guidance for standardized nomenclature (Copies of this reference are available online from www.sae.org or Society of Automotive Engineers, International, 400 Commonwealth Dr., Warrendale, PA 15086-7511.).

b. Transfer functions that approximate the lag in dynamic response of key engine parameters, such as gas generator speed, power turbine speed and power turbine output shaft torque, to fuel flow.

3.7.2.3 Engine and Drive Train Dynamics. Data shall include a block diagram of the engine(s) and drive train components, along with an algebraic representation (rotating moment of inertia, stiffness, resonance frequency, and output shaft speed(s)) of each component of the block diagram).

3.7.2.4 Drive System Torque/Power Limits. Data for torque/power limits shall include MCP, IRP, MRP, and CRP IAW 2.15 above for the following drive system components, on a per-item basis:

a. Uninstalled engine mechanical limit(s).

b. Installed engine output shaft limit(s).

c. Rotor shaft limit(s).

d. Intermediate drive system component limits of sufficient detail to identify performance limiters for discrete flight states.

3.7.3 Production Level. Data shall include design maturity updates to Conceptual Level and Developmental Level data items.

3.8 Substantiating Documentation for Data Verification and Validation. All Air Vehicle Technical Description data shall be categorized as either Basic

Description Data or Derived Data for the purpose of documenting data verification and validation.

3.8.1 Basic Description Data. Basic Description Data shall consist of either physical dimensions under the direct control of the designer, well-documented properties of common materials (e.g., Young's Modulus for 2024-T6 aluminum), or model specification data for NDI/CI (e.g., commercial or government-furnished propellers or engines that are integrated into a developmental item).

3.8.1.1 Substantiating Documentation for Basic Description Data. Substantiation may be included either through reference to documents otherwise available to the United States Government with Government Purpose Rights (GPR) or less data restrictions, or attached as appendices with contractually-specified Data Markings IAW DFARS 252.227-7013(f). (Copies of this reference are available from https://www.acq.osd.mil/dpap/dars/dfarspgi/current/index.html.) Substantiating documentation with data rights more restrictive than GPR shall be segregated into stand-alone annexes with contractually-specified Data Markings IAW DFARS 252.227-7013(f). Substantiating documentation with security classification markings higher than the Air Vehicle Technical Description Report shall be segregated into stand-alone annexes with contractually-specified Data Markings.

3.8.1.2 Substantiating Documentation of Engineering Design Data. Documentation substantiating validation of engineering design data as accurate, adequate, and complete for its intended use(s) IAW MIL-STD-31000 shall be appended to the Report.

3.8.1.3 Type Certificate Data Sheet (TCDS) and Supplemental Type Certificate (STC). Basic Description Data shall also include applicable design TCDSs and STCs for Commercial Item/Non-Developmental Item (CI/NDI) rotorcraft, aircraft, unmanned aircraft systems, propellers, and engines that have been certificated by aviation regulatory authorities (e.g., United States Federal Aviation Administration (FAA), European Aviation Safety Agency (EASA)). A copy of the contemporaneous TCDSs and STCs applicable to the proposed design shall be attached to the Air Vehicle Technical Description Report as appendices.

3.8.2 Derived Data. Derived Data shall consist of any properties of the proposed design which are the result of physical laws acting on the design (e.g., aerodynamic force and moment data, structural stiffness and damping, composite material stress-strain behavior, etc.).

3.8.2.1 Substantiating Documentation for Derived Data. Substantiating documentation for Developmental Level and Production Level Derived Data shall be included in the report either through reference to documents otherwise available to the United States Government with GPR or less data restrictions, or attached as appendices to the report with contractually-specified Data Markings

IAW DFARS 252.227-7013(f). Substantiating documentation with data rights more restrictive than GPR shall be segregated into stand-alone annexes with contractually-specified Data Markings IAW DFARS 252.227-7013(f). Substantiating documentation with security classification markings higher than the Air Vehicle Technical Description Report shall be segregated into stand-alone annexes with contractually-specified Data Markings.

3.8.2.2 Substantiating Documentation for Experimental Data. Substantiating documentation for data derived from experiments (including flight tests) shall include both qualitative and quantitative descriptions of data acquisition processes, associated measurement uncertainties, and assessments of uncertainty propagation for any subsequent calculations required to generate reported data. The term measurement uncertainty is used here as described in industry standards ASME PTC 19.1 and ASME PTC 19.22 (Copies of these references are available from www.asme.org or ASME Information Central Orders/Inquiries, P.O. Box 2300, Fairfield, NJ 07007-2300.). The term uncertainty propagation is used here as described in industry standards ISO/IEC Guides 98-1 through 98-4 (Copies of these references are available from www.ansi.org or American National Standards Institute, 1899 L St NW, #11, Washington, DC 20036-3804.).

3.8.2.3 Substantiating Documentation for Computer-Aided Engineering (CAE) Data. CAE is used here as the subset of Modeling and Simulation (M&S) that includes first-principles-based computational physics and engineering, such as CFD, comprehensive aeroelastic analysis, CSM, CEA, etc. Verification and Validation processes and uncertainty quantification for CAE-based analyses are used here as described in industry standards AIAA G-077 (Copies of this reference are available from www.aiaa.org or American Institute of Aeronautics and Astronautics, 12700 Sunrise Valley Drive, Suite 200, Reston, VA 20191-5807), ASME V&V 10 , ASME V&V 10.1, ASME V&V 20 (Copies of these references are available from www.asme.org or ASME Information Central Orders/Inquiries, P.O. Box 2300, Fairfield, NJ 07007-2300.), and SAE J 2940 (Copies of this reference are available online from www.sae.org or Society of Automotive Engineers, International, 400 Commonwealth Drive, Warrendale, PA 15096.).

3.8.2.3.1 Substantiating Documentation for CAE Tools. Substantiating documentation for data calculated by CAE tools shall include documentation of software and computational hardware sufficient for data traceability and assurance in the event of discovery of technical bugs (e.g., the 1994 Intel Pentium® central processing unit (CPU) Floating Point Division (FDIV) bug). Substantiating system documentation shall include:

a. Identification of software tools by product name, version name and number(s), and developer/publisher,

b. Identification of the computer system used to execute the software, including identification of hardware (including model and generation of the CPU(s), and graphical processing unit(s), (GPU).

c. Identification of the operating systems and utility software, including identification by developer/publisher, specific product name, and version name and number(s).

d. Description of any modified stock software or internally-developed software, to include qualitative and quantitative details of the V&V processes used to assure correct software functionality and applicability of the software for calculation of the Derived Data.

3.8.2.3.2 Substantiating Documentation for CAE Models. Substantiating documentation for data derived from CAE models shall include descriptions of the models, sources and quality of data used to create the models, and qualitative and quantitative details of the V&V processes used to assure appropriateness and applicability of the numerical models for calculation of the Derived Data.

3.8.2.3.3 Substantiating Documentation for CAE Simulations. Simulation as used here describes the exercise of the CAE model by the CAE tool to calculate the Derived Data. Substantiating documentation for data derived from CAE simulations shall include a detailed description of the how the simulation was exercised, and quantitative assessments of numerical uncertainty for the Derived Data.

End of DI-SESS-82291.