CLAIMS

What is claimed is:

1. A vehicle wing assembly comprising:

a multi-element wing including a main wing element and a leading edge slat element;

a deployment mechanism configured to move the multi-element wing between:

a stowed position in which the main wing element blends with a rear panel of a vehicle and the leading edge slat element is concealed under the rear panel of the vehicle, and

an active deployed position in which the multi-element wing is located further away from the vehicle than in the stowed position;

a rotation mechanism configured to adjust an angle of attack of the multi-element wing when in the active deployed position; and

a controller configured to control the deployment mechanism and the rotation mechanism dynamically to adjust drag and downforce based on one or more vehicle operating parameters.

2. The vehicle wing assembly of claim 1, wherein the active deployed position of the multi-element wing is located upward and rearward of the stowed position of the multi-element wing.

3. The vehicle wing assembly of claim 1, wherein the deployment mechanism includes a four-bar linkage system comprising one or more linear or rotary actuators.

4. The vehicle wing assembly of claim 1, wherein the deployment mechanism includes one or more wing support arms, and wherein the rotation mechanism comprises at least one actuator concealed within the one or more wing support arms.

5. The vehicle wing assembly of claim 1, wherein the rotation mechanism comprises a non-back-drivable actuation system configured to maintain the multi-element wing in a set position without requiring continuous power to the deployment mechanism or the rotation mechanism while experiencing aerodynamic loads.

6. The vehicle wing assembly of claim 1, wherein the one or more vehicle operating parameters include at least one of: vehicle speed, acceleration, location, driving mode, steering angle, brake actuation, and/or autonomous driving sensor data.

7. The vehicle wing assembly of claim 1, wherein the rear panel of the vehicle comprises a deck lid, and wherein the main wing element includes a step feature configured to blend with the deck lid when in the stowed position of the multi-element wing.

8. The vehicle wing assembly of claim 1, wherein the leading edge slat element is positioned 3-15 millimeters ahead of the main wing element when in the active deployed position.

9. The vehicle wing assembly of claim 1, wherein the deployment mechanism is configured to deploy the multi-element wing in less than 3 seconds.

10. The vehicle wing assembly of claim 1, wherein the multi-element wing is configured to generate a downforce in a range of 400-500 kg when deployed.

11. The vehicle wing assembly of claim 1, further comprising an impact protection system configured to retract the multi-element wing upon detecting a rear impact.

12. The vehicle wing assembly of claim 11, wherein the impact protection system comprises a mechanical latching mechanism configured to maintain the vehicle wing assembly in a deployed position during normal operation, and release automatically in response to a rear impact force exceeding a predetermined threshold.

13. The vehicle wing assembly of claim 12, wherein the mechanical latching mechanism is calibrated to resist unlatching from aerodynamic loads during normal operation and enable controlled release and retraction specifically in response to impact forces.

14. A vehicle wing system for a vehicle, comprising:

a deployable wing assembly including:

a main airfoil element having a step feature configured to blend with a vehicle body panel when in a stowed position;

a leading edge slat element positioned ahead of the main airfoil element when in a deployed position;

a deployment mechanism coupled to the deployable wing assembly and configured to transition the deployable wing assembly between the stowed position and the deployed position; and

an impact protection system configured to retract the deployable wing assembly upon detecting a rear impact.

15. The vehicle wing system of claim 14, wherein the deployment mechanism is configured to transition the deployable wing assembly between the stowed position and the deployed position in less than 3 seconds.

16. The vehicle wing system of claim 14, wherein the impact protection system is configured to retract the deployable wing assembly until the deployable wing assembly aligns flush with a rear portion of a vehicle.

17. The vehicle wing system of claim 14, further comprising one or more sensors configured to detect a rear impact and trigger a retraction of the deployable wing assembly.

18. The vehicle wing system of claim 14, wherein deployment of the deployable wing assembly provides a change in drag coefficient of approximately +350 counts and a change in lift coefficient of approximately -1000 counts.

19. The vehicle wing system of claim 14, wherein the impact protection system comprises:

a sensor fusion system including one or more of:

a proximity sensor integrated into a rear structure of the vehicle;

a radar sensor configured to detect approaching objects;

a camera system configured to classify potential impact threats; and

a pressure sensors configured to detect an actual impact; and

a controller configured to:

process sensor data to predict a potential impact; and

initiate a wing retraction based on either detected actual impact or a predicted potential impact exceeding a collision probability threshold.

20. A method comprising:

controlling deployment of a multi-element vehicle wing between:

a road mode in which a main wing element of the multi-element vehicle wing blends with a vehicle body panel and a slat element of the multi-element vehicle wing is concealed, and

a track mode in which the multi-element vehicle wing is deployed upward and rearward; and

controlling rotation of the multi-element vehicle wing through a continuous range of angular motion when deployed to adjust one or more of:

a downforce by rotating to a high downforce position,

a drag by rotating to a drag reduction system (DRS) position, and

an aerodynamic balance by rotating to intermediate positions.