Claims:

1. A computer implemented method of in-flight determination of an azimuth of an aerial platform, the platform comprising an inertial measurement unit (IMU) operatively connected to at least one computer device; the computer implemented method comprising:

obtaining data indicative of Earth magnetic field in navigation frame (MF_{NF}) at a flight area of the aerial platform;

defining an auxiliary reference frame comprising an axis X_{AF} being a projection of an initial IMU sensor frame axis on a plane defined by two of a navigation frame axes, wherein the plane is a horizontal plane, wherein Ψ_s is an angle on the plane, between the projection X_{AF} and a predefined direction on the plane;

using the at least one computer device for calculating flight direction of the aerial platform in IMU sensor frame based on IMU acceleration measurements;

during an in-flight phase:

using IMU in-flight gyro measurements for determining transformation from initial sensor frame to current sensor frame;

using IMU magnetometers for obtaining magnetic field measurements in sensor frame and using the at least one computer device for calculating magnetic field values in the auxiliary reference frame based on the magnetic field measurements in sensor frame;

using the at least one computer device for calculating angle Ψ_s based on magnetic field values in the auxiliary reference frame and Earth's magnetic field in the flight area, and thereby obtaining a transformation matrix from sensor frame to navigation frame C_{SF}^{NF}; and

using the at least one computer device for calculating azimuth of the aerial platform based on the flight direction in IMU sensor frame and the transformation matrix C_{SF}^{NF}.

2. The computer implemented method of claim 1, wherein the navigation frame is a local reference frame with respect to Earth.

3. The computer implemented method of claim 1, wherein the predefined direction is north direction.

4. The computer implemented method of claim 3, wherein the navigation frame is North-East-Down.

5. The computer implemented method of claim 1,

wherein the sensor frame is not aligned with the platform frame, and the platform is positioned in a substantially vertical orientation; the method further comprising:

using IMU accelerometers while on the ground for determining flight direction in sensor frame based on gravitation.

6. The computer implemented method of claim 1, wherein the IMU frame is not aligned with the platform frame, and the platform is positioned in a non-vertical orientation, the method further comprising , using IMU accelerometers immediately after launch for determining flight direction in sensor frame based on acceleration measurements vector; and using the flight direction in sensor frame for determining azimuth of the platform notwithstanding IMU frame not being aligned with the platform frame.

7. The computer implemented method of claim 1, wherein the sensor frame is not aligned with the platform frame, the method further comprising:

using IMU accelerometers while on the ground for determining flight direction in sensor frame based on gravitational vector; and

using IMU accelerometers immediately after launch for determining flight direction in sensor frame based on acceleration measurements vector; and using the flight direction in sensor frame for determining azimuth of the platform notwithstanding IMU frame not being aligned with the platform frame.

8. The computer implemented method of claim 1, wherein calculating magnetic field values in the auxiliary reference frame further comprises:

transforming measured magnetic field values in sensor frame to initial sensor frame; and transforming magnetic field values in initial sensor frame to auxiliary reference frame.

9. The computer implemented method of claim 1, wherein for rectifying distortions in in-flight magnetic field measurements, the method further comprises:

using the IMU magnetometers for performing multiple in-flight magnetic field measurements, each taken at a different time;

generating equations, each equation is based on a respective in-flight magnetic field measurement and presents a relation between the respective in-flight magnetic field

measurements, one or more distortions and the Earth's magnetic field; and solving the equations for calculating angle Ψ_s, while considering the one or more distortions.

10. The computer implemented method of claim 9,

wherein each in-flight magnetic field measurement is taken while the IMU assumes a different orientation, and wherein a number of in-flight magnetic field measurements is based on a number of one or more distortions, to thereby provide sufficient independent equations needed for rectifying the one or more distortions.

11. The computer implemented method of claim 10, wherein distortions include one or more of: bias; scale factor; hard iron distortions; and soft iron distortions.

12. The computer implemented method of claim 1 further comprising controlling flight of the platform based on the calculated azimuth.

13. A navigation system mountable on an aerial platform and configured for in-flight determination of an azimuth of the aerial platform, the navigation system comprising an inertial measurement unit (IMU) fixed to the platform and being operatively connected to at least one computer device comprising at least one processor, the navigation system is configured to:

obtain data indicative of Earth magnetic field in navigation frame at a flight area of the aerial platform;

utilize the at least one computer device to define an auxiliary reference frame comprising an axis X_{AF} being a projection of an initial IMU sensor frame axis on a plane defined by two of a navigation frame axes, wherein the plane is a horizontal plane, wherein Ψ_s is an angle on the plane, between the projection X_{AF} and a predefined direction on the plane;

utilize the at least one computer device for calculating flight direction of the aerial platform in IMU sensor frame based on IMU acceleration measurements;

during an in-flight phase:

utilize IMU gyros for obtaining in-flight gyro measurements and determining transformation from initial sensor frame to current sensor frame based on the in-flight gyro measurements;

utilize IMU magnetometers for obtaining magnetic field measurements in sensor frame and utilize the at least one computer device to calculate magnetic field values in the auxiliary reference frame based on the magnetic field values in sensor frame;

utilize the at least one computer device to calculate angle Ψ_s based on magnetic field measurements in the auxiliary reference frame and Earth's magnetic field in the flight area, and thereby obtain a transformation matrix from sensor frame to navigation frame C_{SF}^{NF}; and

utilize the at least one computer device to calculate azimuth of the platform based on the flight direction in IMU sensor frame and the transformation matrix C_{SF}^{NF}.

14. The navigation system of claim 13, wherein the navigation frame is a local reference frame with respect to Earth.

15. The navigation system of claim 13, wherein the predefined direction is north direction and the navigation frame is North-East-Down.

16. The navigation system of claim 13, wherein the sensor frame is not aligned with the platform frame, and the platform is positioned in a substantially vertical orientation; the system is further configured to utilize IMU accelerometers while on the ground for determining flight direction in sensor frame based on gravitational vector; and use the flight direction in sensor frame for determining azimuth of the platform notwithstanding IMU frame not being aligned with the platform frame.

17. The navigation system of claim 13, wherein the IMU frame is not aligned with the platform frame, and the platform is positioned in a non-vertical orientation; the system is further configured to utilize IMU accelerometers immediately after launch for determining flight direction in sensor frame based on acceleration measurements vector; and use the flight direction in sensor frame for determining azimuth of the platform notwithstanding IMU frame not being aligned with the platform frame.

18. The navigation system of claim 13, wherein the sensor frame is not aligned with the platform frame, the system is further configured to:

use IMU accelerometers while on the ground for determining flight direction in sensor frame based on gravitational vector; and

use IMU accelerometers immediately after launch for determining flight direction in sensor frame based on acceleration measurements vector.

19. The navigation system of claim 13 is further configured for calculating magnetic field values in the auxiliary reference frame, to:

utilize the at least one computer device for transforming measured magnetic field values in sensor frame to initial sensor frame and for transforming measured magnetic field values initial sensor frame to auxiliary reference frame.

20. The navigation system of claim 13 is further configured for rectifying distortions in in-flight magnetic field measurements, to:

utilize the IMU magnetometers for performing multiple in-flight magnetic field measurements, each taken at a different time; and the at least computer device is configured to:

generate equations, each equation is based on a respective in-flight magnetic field measurement and presents a relation between the respective in-flight magnetic field measurement, one or more distortions and the Earth's magnetic field; and solve the equations to thereby calculate angle Ψ_s, while considering the one or more distortions.

21. The navigation system of claim 20 wherein each in-flight magnetic field measurement is taken while the IMU assumes a different orientation, and wherein the number of in-flight magnetic field measurements is based on the number of one or more distortions, to thereby provide sufficient independent equations needed for rectifying the one or more distortions.

22. A non-transitory program storage device readable by a computer, tangibly embodying a program of instructions executable by the computer to perform a method of in-flight determination of an azimuth of an aerial platform, the platform comprising an inertial measurement unit (IMU); the method comprising:

obtaining data indicative of Earth magnetic field in navigation frame (MF_{NF}) at a flight area of the aerial platform;

defining an auxiliary reference frame comprising an axis X_{AF} being a projection of an initial IMU sensor frame axis on a plane defined by two of a navigation frame axes, wherein the plane is a horizontal plane, wherein Ψ_s is an angle on the plane, between the projection X_{AF} and a predefined direction on the plane;

calculating flight direction of the aerial platform in IMU sensor frame based on IMU acceleration measurements;

during an in-flight phase:

determining transformation from initial sensor frame to current sensor frame based on IMU in-flight gyro measurements;

calculating magnetic field values in the auxiliary reference frame based on magnetic field measurements in sensor frame;

calculating angle Ψ_s based on magnetic field values in the auxiliary reference frame and Earth's magnetic field in the flight area, and thereby obtaining a transformation matrix from sensor frame to navigation frame C_{SF}^{NF}; and

calculating azimuth of the platform based on the flight direction in IMU sensor frame and the transformation matrix C_{SF}^{NF}.

23. The non-transitory program storage device of claim 22, wherein the method further comprises, rectifying distortions in in-flight magnetic field measurements, comprising:

performing multiple in-flight magnetic field measurements, each measurement taken at a different time; generating equations, each equation is based on a respective in-flight magnetic field measurement and presents a relation between the respective in-flight magnetic field measurements, one or more distortions and the Earth's magnetic field; and solving the equations for calculating angle Ψ_s while considering the one or more distortions.

24. The computer implemented method of claim 1, wherein the platform is a missile or a rocket.

25. The computer implemented method of claim 13, wherein the platform is a missile or a rocket.

26. The non-transitory program storage device of claim 22, wherein the platform is a missile or a rocket.

27. The computer implemented method of claim 1, wherein an axis Z_{AF} of the auxiliary frame coincides with an axis Z_{NF} of the navigation frame.

28. The computer implemented method of claim 13, wherein an axis Z_{AF} of the auxiliary frame coincides with an axis Z_{NF} of the navigation frame.

29. The non-transitory program storage device of claim 22, wherein an axis Z_{AF} of the auxiliary frame coincides with an axis Z_{NF} of the navigation frame.

30. The computerized method of claim 9, wherein the equations are identical or equivalent to:

$$\begin{bmatrix} k1_X & 0 & 0 \\ 0 & k1_Y & 0 \\ 0 & 0 & k1_Z \end{bmatrix} \begin{bmatrix} h^{SF}_{X_{Meas}}(t) \\ h^{SF}_{Y_{Meas}}(t) \\ h^{SF}_{Z_{Meas}}(t) \end{bmatrix} = C^{SF}_{ISF} C^{ISF}_{AF} \begin{bmatrix} cos(\psi_S) & sin(\psi_S) & 0 \\ -sin(\psi_S) & cos(\psi_S) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e^{NF}_X \\ e^{NF}_Y \\ e^{NF}_Z \end{bmatrix} + \begin{bmatrix} kdb1_X \\ kdb1_Y \\ kdb1_Z \end{bmatrix}$$

Where:

$k1_X, k1_Y, k1_Z$ are magnetometer scale factor values;

$h^{SF}_{X_{Meas}}(t), h^{SF}_{Y_{Meas}}(t), h^{SF}_{Z_{Meas}}(t)$ are measured magnetic field values;

C^{SF}_{ISF} is transformation matrix from sensor frame to initial sensor frame;

C^{ISF}_{AF} is transformation matrix from initial sensor frame to auxiliary frame;

$\begin{bmatrix} cos(\psi_S) & sin(\psi_S) & 0 \\ -sin(\psi_S) & cos(\psi_S) & 0 \\ 0 & 0 & 1 \end{bmatrix}$ is transformation matrix from auxiliary frame to navigation frame;

$e^{NF}_X, e^{NF}_Y, e^{NF}_Z$ are Earth magnetic field values; and

$kdb1_X, kdb1_Y, kdb1_Z$ are magnetometer bias values.

31. The navigation system of claim 20, wherein the equations are identical or equivalent to:

$$\begin{bmatrix} k1_X & 0 & 0 \\ 0 & k1_Y & 0 \\ 0 & 0 & k1_Z \end{bmatrix} \begin{bmatrix} h^{SF}_{X_{Meas}}(t) \\ h^{SF}_{Y_{Meas}}(t) \\ h^{SF}_{Z_{Meas}}(t) \end{bmatrix} = C^{SF}_{ISF} C^{ISF}_{AF} \begin{bmatrix} cos(\psi_S) & sin(\psi_S) & 0 \\ -sin(\psi_S) & cos(\psi_S) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e^{NF}_X \\ e^{NF}_Y \\ e^{NF}_Z \end{bmatrix} + \begin{bmatrix} kdb1_X \\ kdb1_Y \\ kdb1_Z \end{bmatrix}$$

Where:

$k1_X, k1_Y, k1_Z$ are magnetometer scale factor values;

$h^{SF}_{X_{Meas}}(t), h^{SF}_{Y_{Meas}}(t), h^{SF}_{Z_{Meas}}(t)$ are measured magnetic field values;

C^{SF}_{ISF} is transformation matrix from sensor frame to initial sensor frame;

C^{ISF}_{AF} is transformation matrix from initial sensor frame to auxiliary frame;

$\begin{bmatrix} cos(\psi_S) & sin(\psi_S) & 0 \\ -sin(\psi_S) & cos(\psi_S) & 0 \\ 0 & 0 & 1 \end{bmatrix}$ is transformation matrix from auxiliary frame to navigation frame;

$e^{NF}_X, e^{NF}_Y, e^{NF}_Z$ are Earth magnetic field values; and

$kdb1_X, kdb1_Y, kdb1_Z$ are magnetometer bias values.

32. The non-transitory program storage device of claim 23, wherein the equations are identical or equivalent to:

$$\begin{bmatrix} k1_X & 0 & 0 \\ 0 & k1_Y & 0 \\ 0 & 0 & k1_Z \end{bmatrix} \begin{bmatrix} h^{SF}_{X_{Meas}}(t) \\ h^{SF}_{Y_{Meas}}(t) \\ h^{SF}_{Z_{Meas}}(t) \end{bmatrix} = C^{SF}_{ISF} C^{ISF}_{AF} \begin{bmatrix} cos(\psi_S) & sin(\psi_S) & 0 \\ -sin(\psi_S) & cos(\psi_S) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e^{NF}_X \\ e^{NF}_Y \\ e^{NF}_Z \end{bmatrix} + \begin{bmatrix} kdb1_X \\ kdb1_Y \\ kdb1_Z \end{bmatrix}$$

Where:

$k1_X, k1_Y, k1_Z$ are magnetometer scale factor values;

$h^{SF}_{X_{Meas}}(t), h^{SF}_{Y_{Meas}}(t), h^{SF}_{Z_{Meas}}(t)$ are measured magnetic field values;

C^{SF}_{ISF} is transformation matrix from sensor frame to initial sensor frame;

C^{ISF}_{AF} is transformation matrix from initial sensor frame to auxiliary frame;

$\begin{bmatrix} cos(\psi_S) & sin(\psi_S) & 0 \\ -sin(\psi_S) & cos(\psi_S) & 0 \\ 0 & 0 & 1 \end{bmatrix}$ is transformation matrix from auxiliary frame to navigation frame;

$e^{NF}_X, e^{NF}_Y, e^{NF}_Z$ are Earth magnetic field values; and

$kdb1_X, kdb1_Y, kdb1_Z$ are magnetometer bias values.

33. The non-transitory program storage device of claim 23, wherein each in-flight magnetic field measurement is taken while the IMU assumes a different orientation, and wherein a number of in-flight magnetic field measurements is based on a number of one or more distortions, to thereby provide sufficient independent equations needed for rectifying the one or more distortions.

34. A non-transitory program storage device readable by a computer, tangibly embodying a program of instructions executable by the computer to perform a method of in-flight determination of an azimuth of an aerial platform, the platform comprising an inertial measurement unit (IMU); the method comprising:

obtaining data indicative of Earth magnetic field in navigation frame (MF_{NF}) at a flight area of the aerial platform;

defining an auxiliary reference frame comprising an axis X_{AF} being a projection of an initial IMU sensor frame axis on a plane defined by two of a navigation frame axes, wherein the plane is a horizontal plane, wherein Ψ_s is an angle on the plane, between the projection X_{AF} and a predefined direction on the plane;

obtaining flight direction of the aerial platform in IMU sensor frame;

during an in-flight phase:

determining transformation from initial sensor frame to current sensor frame based on IMU in-flight gyro measurements;

calculating magnetic field values in the auxiliary reference frame based on magnetic field measurements in sensor frame;

calculating angle Ψ_s based on magnetic field values in the auxiliary reference frame and Earth's magnetic field in the flight area, and thereby obtaining a transformation matrix from sensor frame to navigation frame C_{SF}^{NF}; and

calculating azimuth of the platform based on the flight direction in IMU sensor frame and the transformation matrix C_{SF}^{NF}.

35. The non-transitory program storage device of claim 32, wherein the method further comprises, rectifying distortions in in-flight magnetic field measurements, comprising:

performing multiple in-flight magnetic field measurements, each taken at a different time;

generating equations, each equation is based on a respective in-flight magnetic field measurement and presents a relation between the respective in-flight magnetic field measurement, one or more distortions and the Earth's magnetic field; and solve the equations to thereby calculate angle Ψ_s, while considering the one or more distortions.