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Herwitz

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(54) **GROUND-BASED SENSE-AND-AVOID DISPLAY SYSTEM (SAVDS) FOR UNMANNED AERIAL VEHICLES**

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(65) **Prior Publication Data**

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(51) **Int. Cl.**
G06F 17/10 (2006.01)

(52) **U.S. Cl.** **701/301**; 701/3; 701/120; 701/206; 701/211; 340/435

(58) **Field of Classification Search** 701/3, 701/120, 211, 215, 206, 207, 223, 200, 301; 340/901, 903, 425.5, 435, 426.19
See application file for complete search history.

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Primary Examiner—Gertrude A. Jeanglaude

(57) **ABSTRACT**

The present invention is a Sense-And-Avoid Display System (SAVDS) that integrates airborne target position data from a ground-based radar with unmanned aerial vehicle (UAV) position data from the UAV ground control station (GCS). The UAV GCS receives the UAV position data from a global positioning system (GPS) element in the flight management autopilot system in the UAV. Using a high-resolution display, the SAVDS shows the GPS position of the UAV in relation to other radar-detected airborne targets operating in the same airspace. With the SAVDS co-located adjacent to the GCS computer controlling the UAV, the SAVDS instructs the UAV operator to change the heading and/or elevation of the UAV until any potential midair aircraft conflict is abated. The radar-detected airborne target data and the UAV GPS data are integrated and displayed with georeferenced background base maps that provide a visual method for tracking the UAV and for performing collision avoidance.

3 Claims, 3 Drawing Sheets

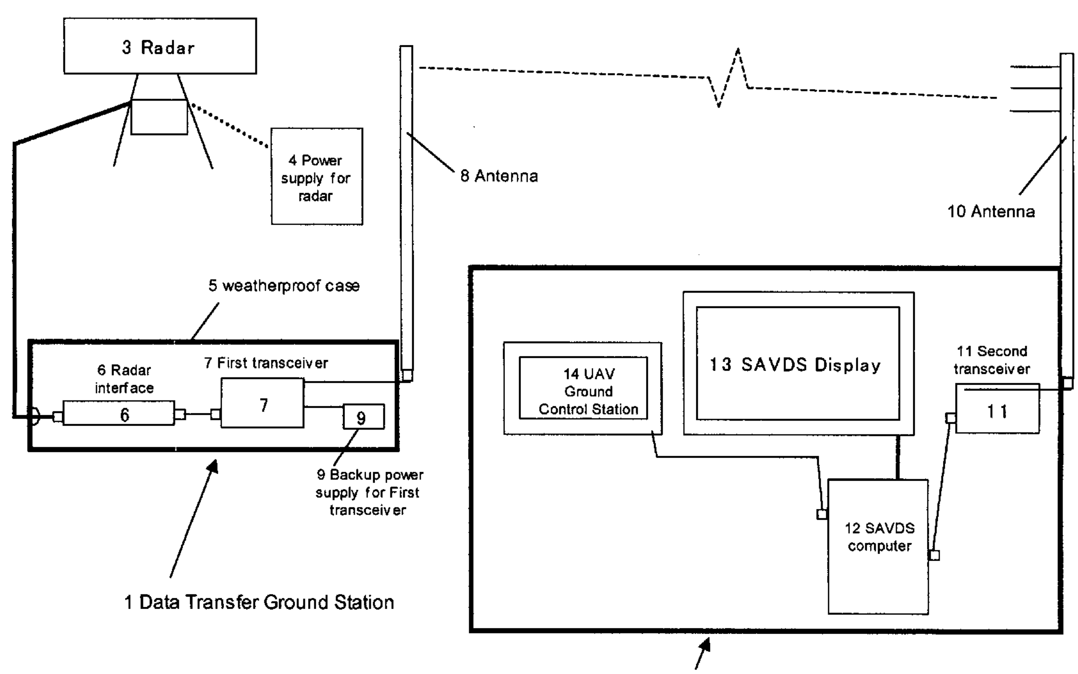
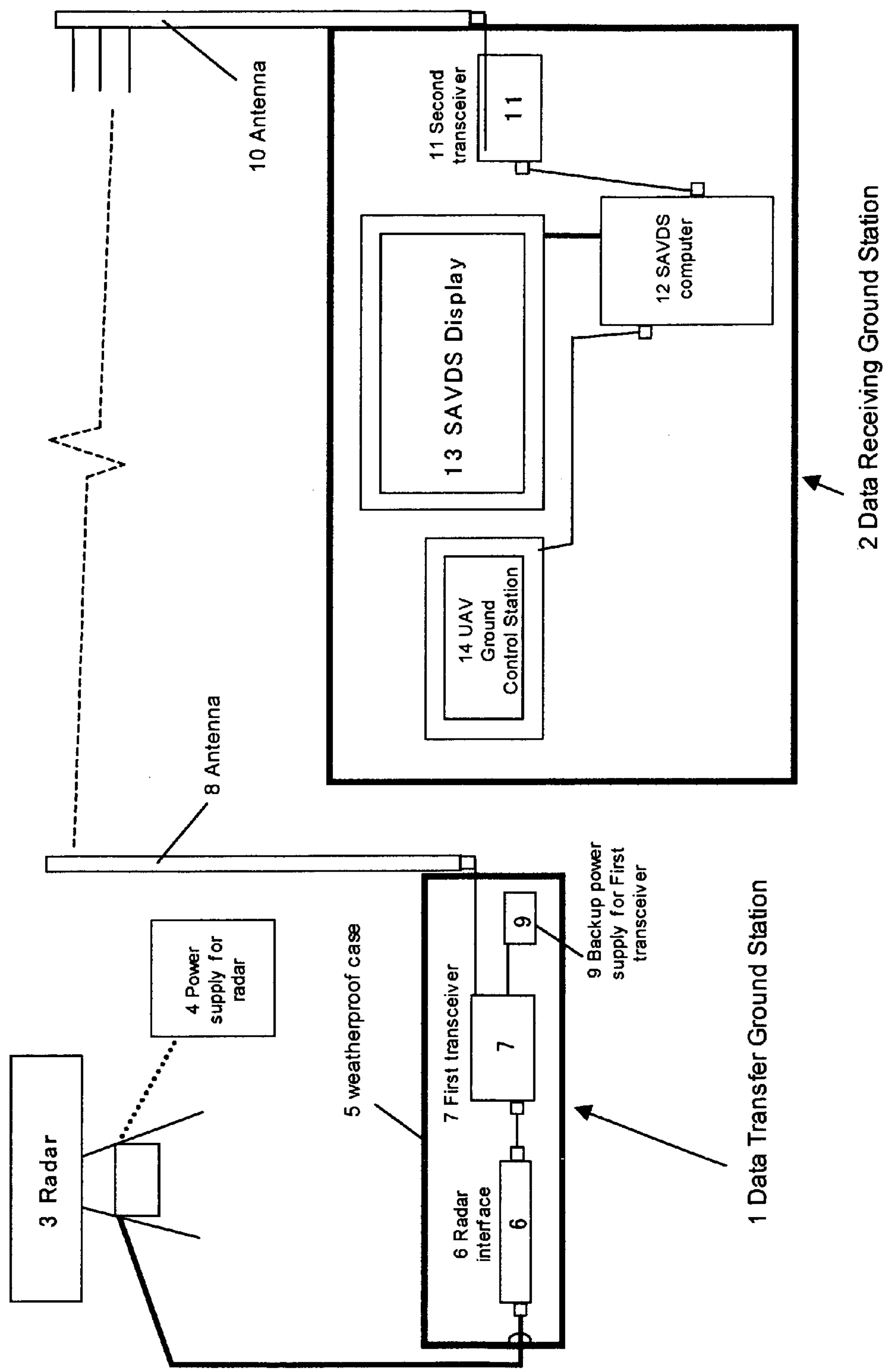


FIG. 1


3 Radar
4 Power supply for radar
5 weatherproof case
6 Radar interface
6
7 First transceiver
7
9
9 Backup power supply for First transceiver
1 Data Transfer Ground Station
8 Antenna
10 Antenna
11 Second transceiver
11
12 SAVDS computer
13 SAVDS Display
14 UAV Ground Control Station
2 Data Receiving Ground Station

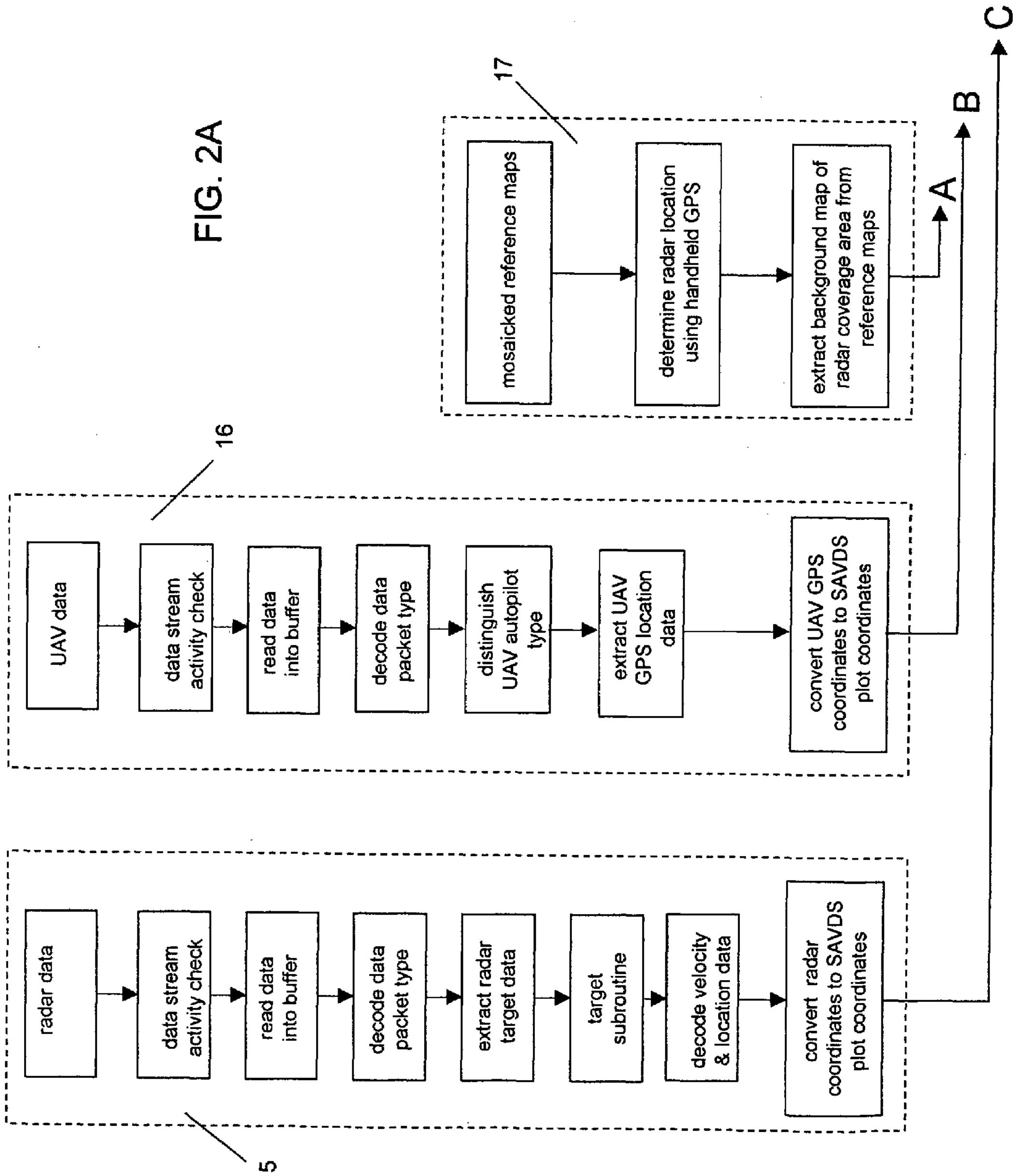
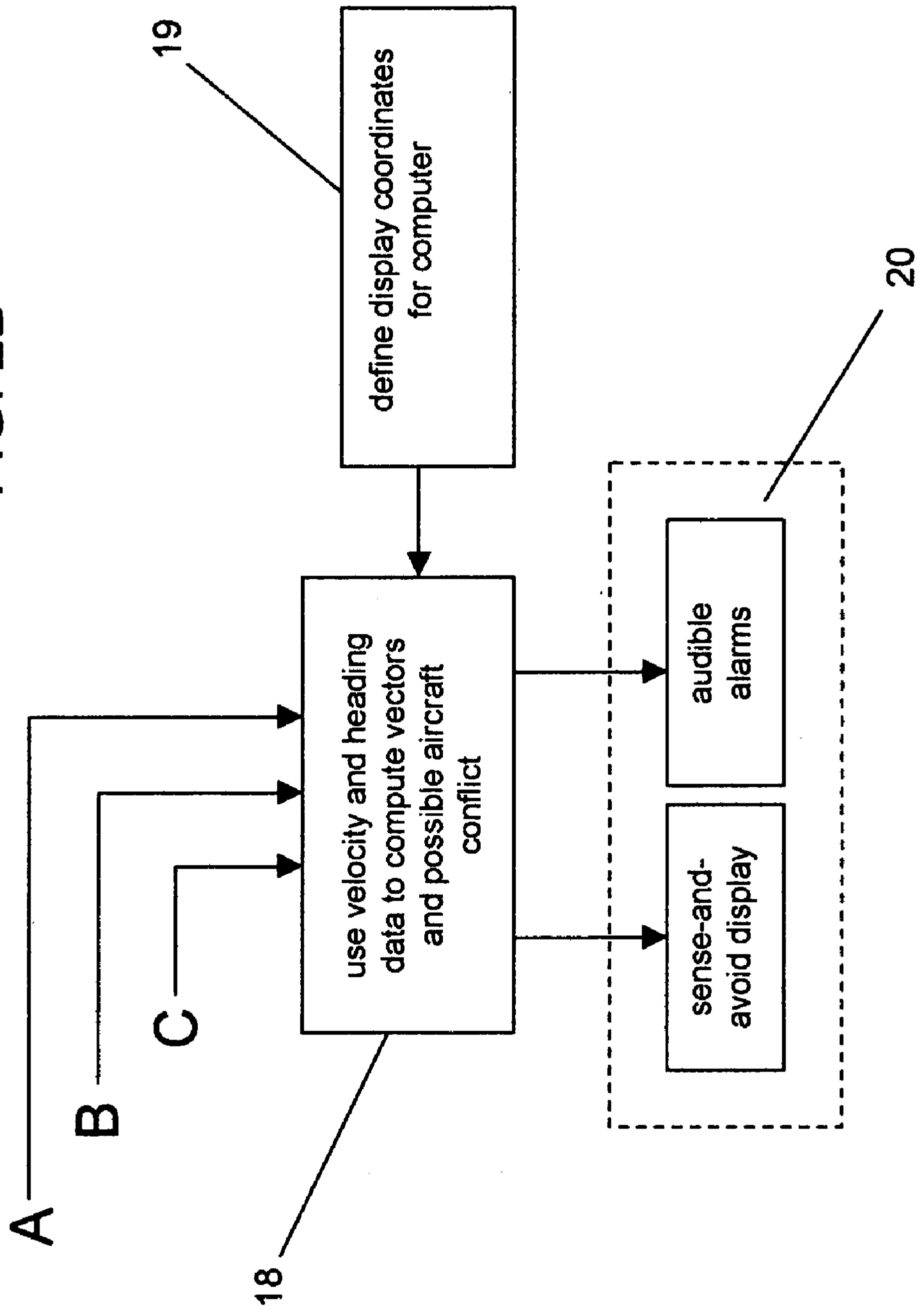
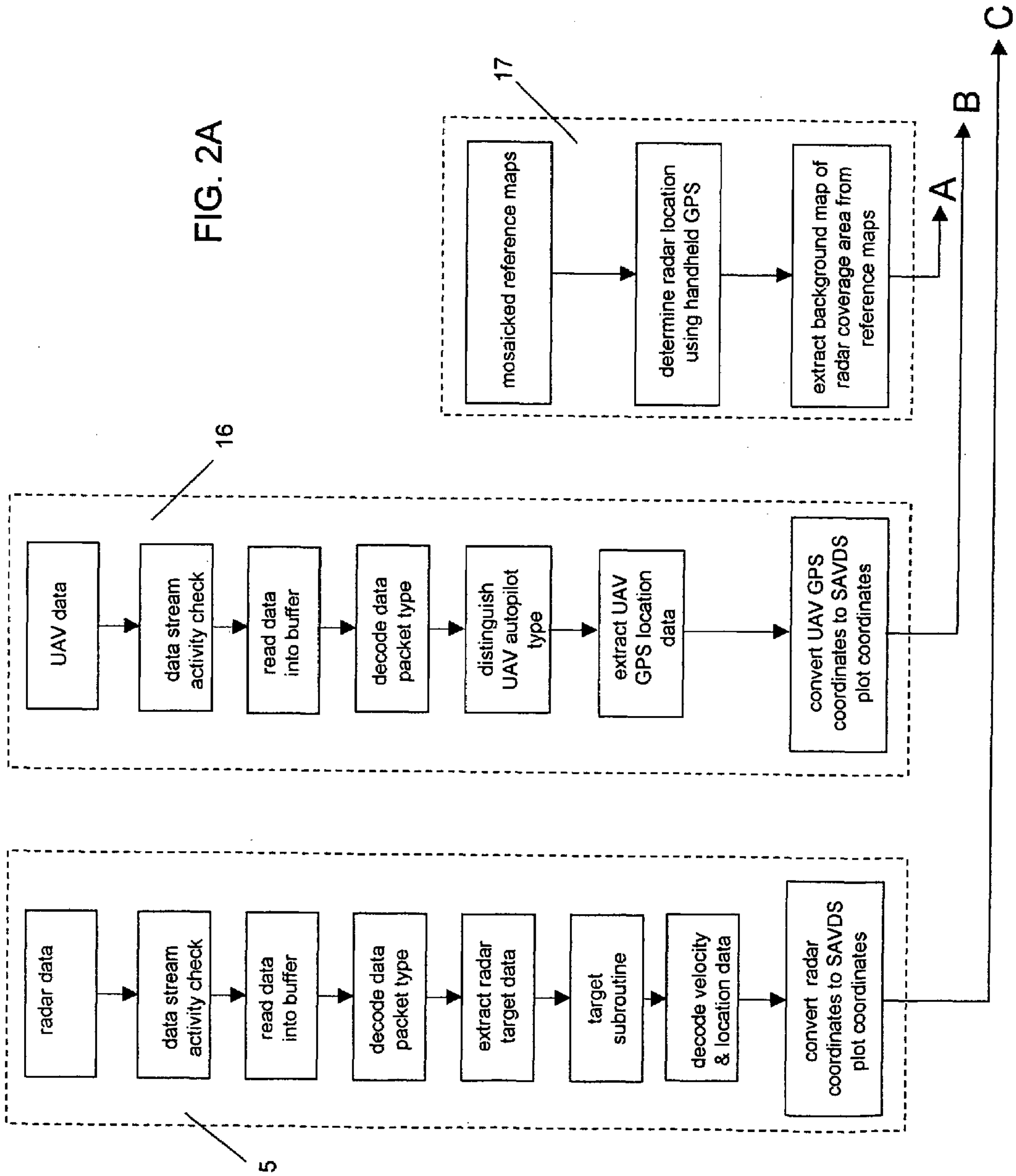

17
mosaicked reference maps
determine radar location using handheld GPS
extract background map of radar coverage area from reference maps
A
B
C
16
UAV data
data stream activity check
read data into buffer
decode data packet type
distinguish UAV autopilot type
extract UAV GPS location data
convert UAV GPS coordinates to SAVDS plot coordinates
15
radar data
data stream activity check
read data into buffer
decode data packet type
extract radar target data
target subroutine
decode velocity & location data
convert radar coordinates to SAVDS plot coordinates

FIG. 2A

FIG. 2B


19
define display coordinates for computer
20
use velocity and heading data to compute vectors and possible aircraft conflict
audible alarms
sense-and-avoid display
A
B
C
18


17
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determine radar location using handheld GPS
extract background map of radar coverage area from reference maps
A
B
C
16
UAV data
data stream activity check
read data into buffer
decode data packet type
distinguish UAV autopilot type
extract UAV GPS location data
convert UAV GPS coordinates to SAVDS plot coordinates
radar data
data stream activity check
read data into buffer
decode data packet type
extract radar target data
target subroutine
decode velocity & location data
convert radar coordinates to SAVDS plot coordinates
15

FIG. 2A

12. The invented SAVDS software continuously checks for incoming radar data. Using the radar, data are received at typical sampling rates of approximately four seconds in real time. These data are read into a memory buffer in order to properly synchronize them with buffered data from UAV data routine **16**. Next the buffered radar data packets are decoded. The typical radar data stream includes a significant amount of data that are unused by the SAVDS software. These unused data (such as radar identification number, port number, grade of data, rotorcraft identifier) are stripped out of the packets. The remaining data identifying specific targets are thus extracted. For each target, the SAVDS software executes a target subroutine that compares and correlates the most recent packet's position data with projections based on the previous packet's target position data and computed velocity vectors. SAVDS then updates the new position and velocity of each radar-detected airborne target (RDAT) and converts this data to a displayable coordinate system. This information is forwarded on to computational routine **18**.

UAV data routine **15** begins with raw UAV data ported into computer **12**. The SAVDS software continuously checks for incoming UAV data. Commercially available UAV autopilot control systems supply GPS data in real time. This data stream is read into a memory buffer in order to properly synchronize it with buffered data from radar data routine **15**. Next the buffered UAV data packets are decoded and fed to the SAVDS software translator. The software translator is coded to extract the UAV's GPS position data. Several commercial UAV autopilot control systems are available. Translator modules have been written into the SAVDS software for selected UAV autopilot control systems. The appropriate translator corresponding to the UAV autopilot used for a UAV mission is selected automatically by the SAVDS software. The SAVDS software compares and correlates the most recent UAV position data with projections based on the previous known position and velocity vector. SAVDS then updates the new position and velocity, and converts the data to a displayable coordinate system. This information is forwarded on to computational routine **18**.

Other aircraft do not pose the only threat to UAVs. Topographical features, such as mountains, are of critical importance to pilots of low-flying UAVs. Readily identifiable topographic surface features also may be of interest. Aerial observation of such surface features may indeed be the primary objective of some UAV flights. These surface features provide a means for tracking the UAV relative to geographic waypoints.

To aid in this surface recognition, SAVDS includes a powerful tool for correlating UAV position to topography and geographic locations. Topographical maps, such as those at 1:250,000 scale developed by the United States Geological Survey (USGS), have been carefully knitted together into seamless mosaicked composite maps. Similar mosaicked maps, based on USGS data at different scales or other georeferenced maps, can be readily loaded into the SAVDS software to provide coverage for other portions of North America or other localities in the world.

Georeferencing routine **17** provides the SAVDS software with this key reference map collection. A hand-held GPS locator is used to determine the position of the ground-based radar **3**. This coordinate information is typed into the SAVDS software, which then extracts a background map of the radar coverage area from the mosaicked reference maps. Radar coverage area refers to the airspace within which the radar detects piloted aircraft and other airborne targets.

Computational routine **18** integrates position, velocity, and heading data from both radar data routine **15** and UAV data routine **16** to compute vectors for the UAV and for the RDAT(s). The resulting information is electronically overlaid on the background map provided by the georeferencing routine **17** and sent to interface routine **20**. Interface routine **20** visually renders the results on display **13**. Aircraft conflicts are identified graphically on the display **13**. Interface routine **20** also issues an audible alarm.

While any comparable computer **12** and associated display **13** common in the art may be used to display SAVDS results, the preferred platform is the G5 model computer manufactured by Apple Computer Corporation of Cupertino, Calif. SAVDS information is optimized for use of Apple Computer Corporation's 23-inch liquid crystal display (LCD) linked with the G5 computer.

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. A ground-based sense and avoid display system for an unmanned aerial vehicle ("UAV") comprising:

a data transfer station, comprising a ground-based radar and a first spread spectrum transceiver that receives radar data from the radar and transmits the radar data;

a data receiving ground station comprising a second spread spectrum transceiver that receives the radar data from the first transceiver, a UAV ground control station ("GCS") comprising a UAV autopilot system that permits manual override, a display system for displaying at least one of a position (x,y,z) and a velocity vector for the UAV and for displaying at least one of a position and a velocity vector for at least one radar detected airborne target ("RDAT"), and a computer that is programmed:

(i) to execute a radar data routine that receives and processes data from the ground-based radar, identifies at least one RDAT and estimates position coordinates and velocity for the at least one RDAT for at least first and second times of estimation;

(ii) to execute a UAV computation routine that receives global positioning system ("GPS") position and velocity data for the UAV from the UAV GCS and estimates position coordinates for the UAV for the at least first and second estimation times;

(iii) to execute an air traffic conflict routine that receives the estimated position and velocity coordinates for the at least one RDAT and for the UAV for the at least first and second times of the estimations, and determines if the UAV and the at least one RDAT will come within a selected threshold distance of each other within a selected time interval, determined with reference to the present time;

(iv) to execute an air traffic warning routine that issues at least one of a visually perceptible signal and an audibly perceptible signal indicating that the UAV and the at least one RDAT will come within the selected threshold distance of each other within the selected time interval; and

(v) to execute a georeferencing and interface routine that provides a geographical background map of a radar coverage area and that provides visually perceptible icons on the map representing the UAV position and the at least one RDAT position for at least one of the at least first and second estimation times.

2. The system of claim **1**, wherein said computer is further programmed to remove irrelevant radar data, drawn from the group of said radar data received for said at least one RDAT and including at least one of radar identification number, port number, grade of said data or rotorcraft identifier, before or at the time said radar data routine is executed.

3. The system of claim **1**, wherein said computer is further programmed to provide at least one of a visually perceptible estimation signal and an audibly perceptible estimation signal indicating an estimate of a time, if any, determined with reference to said present time, that said UAV and said at least one RDAT will first come within said selected threshold distance of each other within said selected time interval.

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