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ASA / ASAS

Tracking Information (committee secretary only)	
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Short Title for Change Issue:	Loss of Own-Ship Directionality

Topic:		ASA		High-level		ASAS		STP		ASSAP		CDTI

Document Reference: DO-289		Originator Information:	
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Table/Figure number(s)		Other	

Proposed Rationale for Consideration (originator should check all that apply):	
	Item needed to coordinate with other documents
X	ASA MASPS
	1090 MHz Link MOPS
	UAT Link MOPS
	TIS-B MASPS
	Previously written CDTI MOPS
	Other (include document title):
	Item needed for harmonization with international requirements
	Item identified during recent ADS-B development activities and operational evaluations
	MOPS clarifications and correction item
	Validation/modification of questioned MOPS requirement item
	Military use provision item
X	New requirement item

Nature of Issue:		Editorial	X	Clarity	X	Performance	X	Functional

Issue Description:

Loss of Own-Ship directionality has been identified as a potential source of hazardously misleading information. This issue paper is intended to first, illustrate how the current CDTI requirements do not adequately constrain Own-Ship directionality design requirements to prevent hazardously misleading information and second, to propose new requirements to contain these hazards.

I - Hazard Description

A Cockpit Display of Traffic Information (CDTI) display provides traffic information to the flight crew/pilot to increase awareness of traffic in a specific volume of airspace. This traffic information may be used as an aid to visual acquisition of other aircraft, departure/arrival spacing, and potentially more critical applications. Traffic information must not mislead the pilot into maneuvering his aircraft into a hazardous situation.

CDTI display in a track-up mode requires the own-ship's horizontal velocity vector to determine its course (ground track). When the aircraft velocity vector has a magnitude of zero (or below some low threshold velocity), direction is undefined. Using last known valid own-ship track for track-up display orientation could result in hazardously misleading information about proximate traffic relative bearing and orientation as the own-ship deviates from last known valid track (e.g. hovering aircraft with zero horizontal velocity, rotating about its vertical axis). This is problematic in that it could provide a misleading yet compelling assertion that "track" is sufficiently accurate. A pilot could improperly maneuver an aircraft

based on assumptions of future traffic positions based on this misleading information from the CDTI. CDTI performance requirements must define design constraints to prevent these hazards.

Figure 1 illustrates a CDTI in track-up mode while (erroneously) displaying traffic information from last known valid track of 045º where the actual track is 090º. Figure 2 illustrates the actual traffic positions and orientations for a track of 090º. The relative bearing (azimuth) to each target from the own-ship's point of reference is clearly erroneous and although traffic directionality is numerically correct, the relative direction with respect to the own-ship's point of reference is misleading.

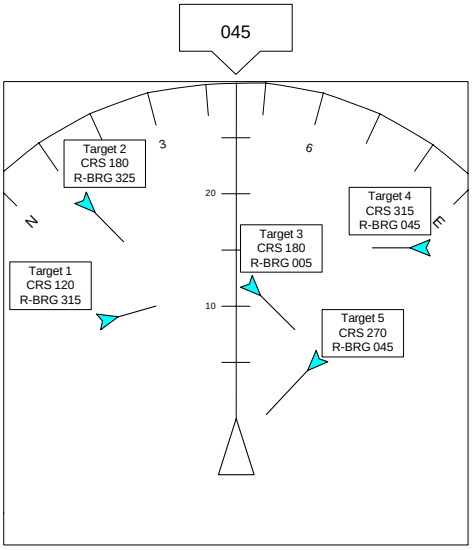

Figure 1: CDTI Display with Last Known Valid Track-Up Orientation

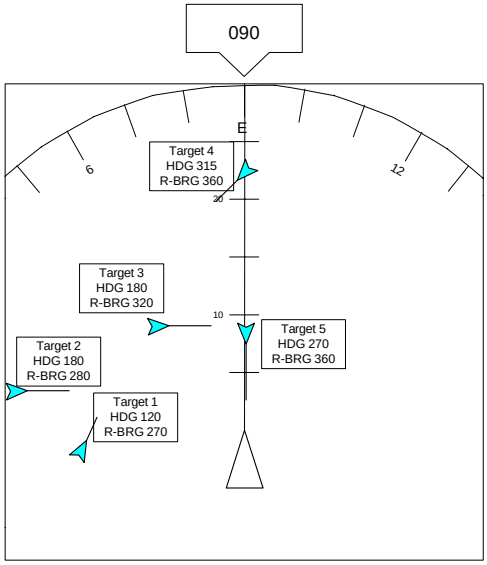

Figure 2: CDTI Display with True Track-Up Orientation and Actual Traffic Locations

Target ID	Aircraft Track (Course)	Target Perceived Relative Bearing	Target Actual Relative Bearing	Azimuth & Orientation
Own-Ship	090º	-		Own ship symbol indicates a ground track of 045º.
Target 1	120º	315º	270º	Target appears to be ahead and left of course (10 o'clock), Side Convergent Acute and crossing flight path 10 miles ahead of own-ship. Target is actually 90º left of course (9 o'clock) Side Convergent Acute crossing flight path 20 miles ahead of own-ship.
Target 2	180º	325º	280º	Target appears to be ahead and left of course (11o'clock), Side Convergent Oblique crossing flight path 5 miles ahead of own-ship. Target is actually ahead and left of course (9 to 10 o'clock), Directly Convergent crossing flight path <5 miles ahead of own-ship.
Target 3	180º	005º	320º	Target appears to be ahead and slightly right of course (12 o'clock), Side Divergent Acute and not crossing the aircraft flight path. Target is actually ahead and left of course (11 o'clock), Directly Convergent and crossing flight path approximately 10 miles ahead of own-ship.
Target 4	315º	045º	360º	Target appears to be ahead and right of course (1 o'clock) and Directly Convergent crossing flight path 15 miles ahead of own-ship. Target is actually dead ahead (12 o'clock) 25 miles and Side Divergent Acute.
Target 5	270º	045º	360º	Target appears to be ahead and right of course (2 o'clock), Side Convergent Acute, crossing flight path at own-ship present position. Target is actually dead ahead (12 o'clock) ~8 miles on a Head-On on collision course.

Geometry Descriptors

Each descriptor describes the relative angles of aircraft converging or diverging:

Side Convergent Acute: one aircraft converges from the side to the other aircraft & the convergence angle is < 90°.

Side Convergent Oblique: one aircraft converges from the side to the other aircraft & the convergence angle is > 90°.

Directly Convergent: one aircraft converges from the side to the other aircraft & the convergence angle is 90°.

Side Divergent Acute: one aircraft diverges from the side to the other aircraft & the divergence angle is < 90°.

Side Divergent Oblique: one aircraft diverges from the side to the other aircraft & the divergence angle is > 90°.

Directly Divergent: one aircraft diverges from the side to the other aircraft & the divergence angle is 90°.

Head On: represents a "head on" encounter, where the two aircraft are converging head on.

Originator's proposed resolution:

II - Proposed Requirements

Two proposals are provided herein, first, by modifying the existing document structure to capture specific requirements and second, to group the requirements into a separate section, 3.3.3.x.x.x Loss of Own-Ship Directionality.

See Figure 3, Proposed Solution: North-Up Display with Traffic

Proposal 1:

3.3.3.1.1.5 Track-Up / Heading-Up Orientation

Add after "Heading Up" and before "Notes":

When own-ship directionality is insufficient:

- The degraded condition shall be clearly indicated (i.e., flagged) on the display.
- Track-Up and Heading-Up modes are undefined. Hence, either of these two modes shall be disabled.
- A North-Up mode must be selected by the user (with the North-up mode clearly indicated)

3.3.3.1.2.1 Own-Ship Symbol

After Note 1

- The own-ship symbol should indicate directionality (e.g., chevron), and the front of the symbol that conveys directionality (e.g., apex of a chevron) should correspond to the aircraft location.

When own-ship directionality is insufficient:

- The own-ship symbol shall be non-directional (e.g. circle), positioned at the center of the display, and the aircraft location should correspond to the center of the non-directional symbol.

3.3.3.1.2.2 Basic Traffic Symbols (Directional and Non-directional)

After 1st note:
The CDTI shall position each traffic symbol at a location on its display representing range and bearing with respect to own-ship. Furthermore, if *traffic* directionality data is available, traffic symbology should be directional.

When own-ship directionality is insufficient:

- The CDTI shall not position traffic symbols on the CDTI unless the CDTI is in North-Up mode.

- Traffic target symbols may be displayed representing absolute position and track angle on the CDTI if the display is switched to North-Up display mode.

Proposal 2:

3.3.3.X.X.X Loss of Own-ship Directionality

If own-ship directionality becomes unusable (such as from equipment failure, degraded signals, or insufficient ground-track speeds), the following display issues must be addressed:

a. **Display Orientation**. The degraded condition shall be clearly indicated (i.e., flagged) on the display. When own-ship directionality is lost, Track-Up and Heading-Up modes are undefined. Hence, either of these two

modes shall be completely disabled. A North-Up mode must be selected by the user (with the North-up mode clearly indicated)

b. **Own-ship Symbol.** The own-ship symbol shall be non-directional (e.g. circle), and the aircraft location should correspond to the center of the non-directional symbol.

c. **Own-ship Symbol Position** The own-ship symbol shall be positioned at the center of the display, so as not to imply own-ship directionality.

d. **Displayed Traffic.** Traffic shall not be displayed unless the display orientation is North-Up. Traffic target symbols may be displayed representing absolute position and track angle on the CDTI if the display is switched to North-Up display mode.

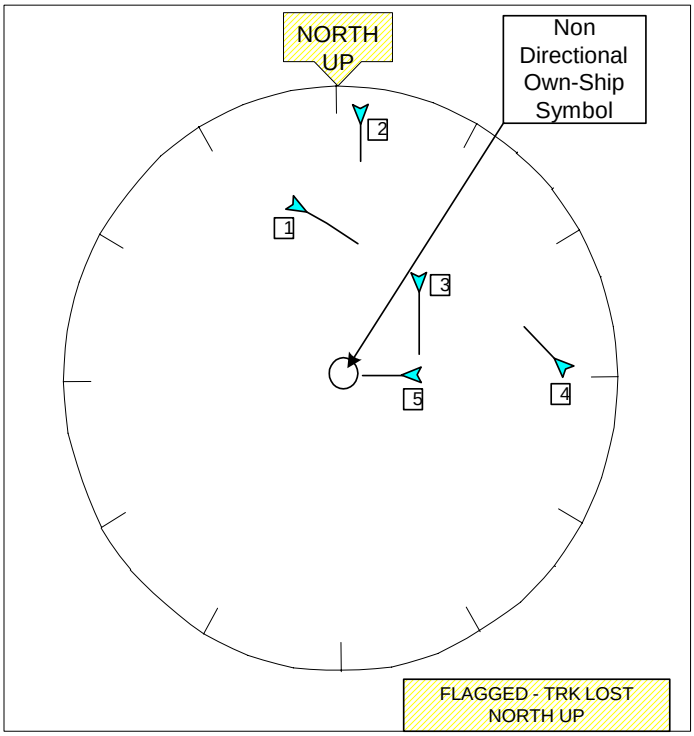

Figure 3: Proposed Solution – Non-Directional Own-Ship Symbol with CDTI in North-Up Orientation

Note: Own-Ship display symbology and display requirements are consistent with requirements stipulated in RTCA/DO-257A (Draft-8d) Minimum Operational Performance Standards for the Depiction of Navigational Information on Electronic Maps.

Comments from Jim Maynard (UPS Aviation Technologies), 07 April 2003:

1. We should separate our requirements regarding the loss of own-ship directionality information according to ASA level and according to whether we are considering airborne or surface applications. The requirements on CDTI installations that support only the Basic ASA Level applications can be, ***and should be***, less stringent than requirements on CDTI installations that support the Advanced ASA Level applications.
2. For the Basic ASA Level *surface* applications (i.e., ASSA - Airport Surface Situational Awareness and FAROA - Final Approach and Runway Occupancy Awareness), a General Aviation aircraft without a heading sensor should be permitted to use the Track-Up orientation using the last valid track angle — even though, as Steve's Figures 1 and 2 indicate, the information displayed may be misleading.
    a. Any hazard associated with this misleading display orientation is mitigated by the pilot's usual procedure of looking out the window to obtain situational awareness. (The "Airport Surface Situational Awareness" application is *not* the more demanding "Blind Taxi" application!)
    b. Any hazard associated with this misleading display orientation can be further mitigated by informing the pilot that the CDTI display may be oriented incorrectly: e.g., "TRK LOST" and "DISPLAY MAY BE ORIENTED INCORRECTLY" messages on the display. The own-ship symbol should also be changed to a non-directional shape (e.g., circle or regular polygon).
    c. Both the ASSA and FAROA applications require that at least a minimal surface map be shown on the CDTI. Such a surface map will further assist the pilot correlate the orientation of the display to the view out the window.
    d. Automatically removing all targets from the display when the ground speed falls below about 5 knots (or whatever speed causes own-ship track angle to be unreliable) would be undesirable. As Bob Hilb pointed out in today's teleconference, that would deprive the pilot of the CDTI's capability of showing traffic all around him just when he needs that capability the most: when stopped on the runway before to starting his take-off roll, or when stopped at a hold line before entering or crossing an active runway.
    e. I think that automatically switching the display to a North-Up orientation when the ground speed falls below 5 knots (or whatever speed causes own-ship track angle to be unreliable) and automatically resuming a track-up orientation when the ground speed next exceeds a threshold, would also be undesirable. Such repeated switching of display orientation would, in my view, only serve to irritate the pilot.
3. For the Basic ASA Level airborne applications (i.e., Enhanced Visual Acquisition and Conflict Detection), the loss of GNSS track angle information at low ground speeds is an event that would usually occur only in helicopters or airships. We reduce the probability of this happening, confining it only to a failure condition, by requiring CDTI installations in helicopters and airships to have a heading sensor . Alternatively, we could require that helicopters and airships either (a) have a heading sensor installed, or (b) revert to a north-up display at low ground speeds, as Sheila told us had already been required of some TAWS display installations.
4. Incidentally, we should also require that CDTI installations that are also to be used as a TCAS traffic displays should have a heading sensor data provided either directly to the CDTI or to the ASSAP function that drives the CDTI. This is necessary because TCAS provides bearings of traffic targets relative to the own-ship heading, whereas other surveillance sources such as ADS-B and TIS-B would provide traffic locations in latitude and longitude, not relative to the own-ship heading.
5. In my view, it is reasonable to mandate the installation of heading sensors on aircraft that support the Advanced ASA level. These will be higher-end aircraft that probably already have heading sensors, anyway.
6. CDTI installations that do have heading sensors, and that use the Track Up display orientation, should be permitted to revert to a Heading Up display when the track angle is unreliable because of low ground speed – without having to display a message that the display is now in a Heading Up mode. At such low ground speeds, heading is probably the best estimate of track angle, anyway!
7. Finally, an editorial comment on Steve's Figure 3. It indicates a red (!!!) color being used to call

attention to the lack of a numerical own-ship heading or track angle and to the "TRK LOST" message. The loss of own-ship directionality information is not a condition that requires immediate action by the pilot to avoid a hazard, so the color red should not be used.

Comments by Chuck Manberg (ACSS),4/7/03:

1. Removal of the compass rose scale when the display orientation is selected North-Up and displaying the targets relative to the north up orientation. This would eliminate confusion in the cockpit with the primary HSI's. For example, if the aircraft heading is 180 deg. the primary HSI would indicate 180 deg. on its compass rose and the CDTI would indicate 0 degrees.
2. When displaying target relative positions to own aircraft, providing a display of an aircraft symbol reminds the pilot the position of the nose of the aircraft. Providing an aircraft symbol for own aircraft instead of a circle would be preferred.

Comments by Bill Petruzel (FAA – Flight Standards /AFS-400), 4/8/03:

In addition to agreement with the points made by the author of this paper, I am of the opinion at this time that all operations on the surface must be done in the "North Up" mode when it comes to reference to the "CDTI" specifically. There is simply no reason at all for a map in the cockpit orienting itself on the heading of one's own aircraft while taxiing around on the surface of the airport.

This conforms to reference to current airport page layouts in the let down plates from Jeppeson and DOT where they are all in 'North up' orientation.

Comments by Stephen George (FAA – Aircraft Certification/AIR-130), 4/9/03:

FAA Advisory Circular 25-11, "Transport Category Airplane Electronic Display Systems", section 9. Map Mode Considerations, item d, states:

8(d) When evaluating map failure modes, including failures induced by the symbol generator or the source navigation computer, *considerations must be given to the compelling nature of a map display. It has been demonstrated that gross map position errors can go undetected or unbeleived because the flight crew falsely relied on the map instead of correct raw data. …*

The applicability of this guidance from AC 25-11 is compounded as the moving map (on a CDTI) depicts both own-ship and traffic targets in motion, either airborne, or on the surface. The CDTI dipicts traffic relative bearing, range and orientation which can display misleading information to the pilot/flight crew if the heading or track is not accurately known. This hazard exists independent of the application being performed with the CDTI and must be appropriately eliminated or controled based on the frequency of occurance and consequential severity of a mishap.

Avionics manufacturers addressed a similar problem with North-Up vs. Heading/Track up in Supplemental Type Certification of Enchanced Ground Proximity Warning System (EGPWS). A minimum gound speed was required to calculate track for display in the Track-Up orientation. The resulting certification requirements were to either blank the display or switch to a North-Up mode in a transitionary phase; transitioning from 15 to 35 knots increasing groundspeed and 25 to 5 knots decreasing groundspeed.

A North-Up only requirement should stand for all applications/service levels, as the information presented on the CDTI display in any other orientation is misleading regardless of the application.

Comments by Shiela Mariano (FAA – Aircraft Certification/AIR-130), 4/10/03:

Rewording of requirements description:

Proposal 1:
3.3.3.1.1.5 Track-Up / Heading-Up Orientation

Add after "Heading Up" and before "Notes":

When own-ship heading/track information is unknown:

- The display must be blanked with a failure condition annunciation, or.
- A north-up display must be presented with a North-Up Mode Annunciation. (This may be pilot selectable or automatic, if pilot selectable, indication of the failure should be provided to the pilot to switch to the north-up display.)

3.3.3.1.2.1 Own-Ship Symbol

After Note 1

- The own-ship symbol should indicate directionality (e.g., chevron), and the front of the symbol that conveys directionality (e.g., apex of a chevron) should correspond to the aircraft location.

When own-ship heading/track information is unknown:

- The own-ship symbol must be presented non-directional (e.g. circle), if the mag/track heading is provided on the display, or
- Presented as a chevron, if the display is North-up Mode.

3.3.3.1.2.2 Basic Traffic Symbols (Directional and Non-directional)

After 1st note:
The CDTI shall position each traffic symbol at a location on its display representing range and bearing with respect to own-ship. Furthermore, if traffic directionality data is available, traffic symbology should be directional.

When own-ship heading/track information is unknown:

- The CDTI shall only display the ownship position with a failure annunciation of "loss of ADS-B traffic information";
- Traffic symbols on the CDTI may be displayed, if North-up mode is selected or available..

Proposal 2:

3.3.3.X.X.X Loss of Own-ship Directionality

If own-ship directionality becomes unavailable (such as from equipment failure, degraded signals, or insufficient ground-track speeds), the following display issues must be addressed:

a. Display Orientation. When own-ship directionality is unavailable, the display shall be blanked, with a failure indication or presented in north-up mode.
b. Own-ship Symbol. The own-ship symbol shall be non-directional (e.g. circle), if the display is not in North-Up Mode.
c. Displayed Traffic. Traffic must be presented in the North-up Display mode. When the failure occurs on the heading/track display, the traffic shall be removed from the display and a failure annunciation shall be presented on the display " loss of ADS-B traffic information"

Comments by Bob Hilb (UPS), 4/17/03:

Jim Maynard has done an excellent job in including my concerns and comments so I wouldn't repeat what he has said. But, I will add additional comments on the airborne vs. the surface use of traffic and any potential hazards.

I agree that while airborne, gross errors in bearing can be misleading and may present a minor hazard, e.g., the pilot looks on the wrong side of the aircraft for traffic. However, sometimes controllers give the opposite clock position when calling traffic or not know that the aircraft has started a turn when the call is made either which could result in a large bearing error. I see the hazard at the same level that currently exists with controllers calling traffic. The pilot is always responsible for seeing and avoiding and thus must look in all directions although their scan may momentarily concentrate in one area. I am confident that current analysis will show that the loss of track will be extremely rare except for those aircraft mentioned already by Jim and will have less of an effect on the pilot's scan than controller callout of traffic thus increasing the level of safety.

On the other hand, on the surface, I have seen no one explain what the potential hazard is. I understand that the traffic picture displayed may not be accurate if the track (heading) is inaccurate, but no one has related that to a hazard and the potential consequences of that hazard. When I am taxiing I look for aircraft in front of me, whether on my taxiway or runway, or one crossing in front of me. Except on the runway, I only care about traffic that is very close to me. No one will ever convince me that if I see someone in front of me I will taxi into them because my display does not show them in front of me. Traffic display anywhere else then in front of me is on no consequence no matter how wrong it is.

The runway is a different case. At controlled airports, the controller has responsibility for separation. I am not allowed on the runway unless the controller has given me a clearance to be there. I am required to visually clear the runway as a backup to the controller. Traffic on a surface map adds a third layer of redundancy (and a fourth, if both aircraft are equipped). If the traffic display is accurate and there is traffic that is a threat to me that the primary and secondary methods fail to detect, then this extra layer has dramatically increased safety. If there is traffic there that is a threat and the primary and secondary methods have failed and now my display also does not show the traffic as a threat, then I am no worse off then I would be without the display. In the case of uncontrolled airports, we lose the primary (the controller) but still have the visual clearing and I believe my logic is still valid.

I fully support the idea that if track (heading) is possibly in error the display should indicate that to the pilot. However, at least on the surface, I see no reason to remove map or traffic information from the display or automatically revert to a North up display. In the latter case, I believe switching back and forth between track up and North up will be confusing and distracting to the pilot and workload intensive if manually required. We have to remember that, on the surface, discrepancies are quite apparent to the pilot. If I am in position on the runway if the track (heading) is incorrect, the runway will be at an angle just like it would be at an angle on North up display (obviously not the same angle). However, just like on a North up display, the traffic relative to the runway is still correct. If someone is on final to the runway it will show that. If someone is on the other end of the runway, it will show that. If someone is approaching the runway on an intersecting taxiway at a high speed, it will show that. In other words, all of the critical runway incursion/accident scenarios will be quite apparent to the pilot.

My conclusion is that having a display with traffic that may, in rare cases (taxiing at very slow speeds and in a turn without valid heading information) may make the display picture a little more difficult to interpret. However, in those cases, we have no degradation of safety from the current operational environment. The remainder of the time (the vast majority of the time) there will be a dramatic increase in safety.

Working Group 4 Deliberations on April 22, 2003

This Issue Paper was reviewed and discussed at the WG4 meetings held April 22 & 23, 2003 at RTCA, Inc.