April 19, 1999

William J. Hughes Technical Center Test Suite Analysis Work for "RWG Approved Changes 1.0 to DO-85A"

During TCAS flight testing, nuisance failures of the barometric altitude credibility monitor had been observed. They occurred during vertical rate maneuvers approaching 1.0g in acceleration. Discussions with Mitre/CAASD indicated that the barometric altitude credibility monitor was designed to only handle approximately 0.5g accelerations maximum. It was decided that the altitude credibility window should be modified to avoid regular occurrences of TCAS system failures during climbouts and during resolution advisories (RAs) where the pilot responds aggressively.

The Requirements Working Group (RWG) agreed in March 1999 to widen the credibility window of the alpha-beta tracker used to track own aircraft altitude (airdata-tracker) to ensure that the tracker would be able to maintain track on own aircraft during a 1.25g vertical acceleration. This change prompted a re-examination of the credibility window used by the 100-ft and 25-ft altitude trackers. It was agreed that the three altitude trackers should perform similarly. These issues and the corresponding modifications to the system requirements are documented in Change Proposal 98 (CP98).

Personnel at the William J. Hughes Technical Center performed an analysis of the effects CP98's resolution had on the existing Collision Avoidance System (CAS) test suite. The test suite verifies coverage of the requirements defined by the CAS Requirement Specification (CRS) of DO-185A.

The Technical Center was tasked with analyzing what effects the parameter changes implemented to resolve CP98 had on the test results. Further, if requirements coverage was no longer attained, the Technical Center was to make additions to the test suite to reacquire coverage. Since the Technical Center's TCAS simulation is based on pseudocode that is a verified implementation of the CRS rather than the CRS itself, some assumptions were necessary to perform these tasks. Technical Center personnel assumed that identification of lost test suite coverage in the pseudocode due to implementing CP98 could be projected onto the CRS. This was done by using the CRS-pseudocode mappings produced for the verification and validation efforts performed for the baseline TCAS requirements. This baseline is referenced by TSO C119B, and is comprised of DO-185A specifications and CPs 1-92 that were approved by the RWG. These mappings were assumed to still be valid with CP98 implemented. It was further assumed that there was only a loss of CRS coverage where there was a corresponding loss of pseudocode statement coverage. Therefore, only those requirements specified in the CRS that corresponded to lines of pseudocode that were no longer executed by the test suite were examined. This work identified three Macro transitions not executed by the test suite that were executed before CP98's resolution was implemented. Tests were then developed that executed those transitions. Those new tests were then added to the test suite so that the test suite again has full requirements coverage.

Below is a more detailed breakdown of the process used at the Technical Center for its test suite analysis:

1. Ran entire test suite (306 tests) against Technical Center's pseudocode based simulation (FTEG) before and after the resolution to CP98 was implemented.

2. Identified which tests produced different outputs after CP98's resolution. Since CP98's resolution included reducing the allowable range of values for two fields (Min_Softness & Max_Softness), only tests that produced differences not involving the values of those fields were considered.

3. Performed a before and after CP98 pseudocode statement coverage analysis for the entire test suite.

4. Observed a total of six lines of pseudocode that were no longer executed after CP98's resolution was implemented. These six lines of pseudocode were found to be three logical code blocks in three separate routines. (See Attachment A.)

5. Identified which tests the lost pseudocode coverage previously was executed in. Confirmed that the same tests which produced substantial differences in results (Step 2) were also the tests which previously provided coverage for the three blocks of code not executed post-CP98. Four tests were identified (EN03TS17, EN03TS71, EN03TS75, EN04TS22). Two of these tests previously hit the same code no longer covered by the test suite. (EN03TS17, EN03TS75)

6. Used traceability matrices developed from the CRS and pseudocode as it is defined for TSO C119B to map the blocks of pseudocode not executed to their corresponding Macro transitions in the CRS. (See Attachment B.) As anticipated, it was observed here and in step 4 that the requirements no longer executed by the test suite was the failure of the altitude credibility check and the subsequent coasting of the tracker being used.

7. Used identified tests (EN03TS17, EN03TS71, EN04TS22) as a basis for developing new tests that would reacquire lost pseudocode coverage. This was done by adding accelerations that would fail the credibility check and coast the various trackers.

8. Three new tests were developed (EN03TS79, EN03TS80, EN04TS49) which gave the test suite (now 309 tests) the same pseudocode statement coverage it had before CP98 was implemented.

9. Performed a visual inspection of two sets of TSIM output files from the three new tests and the three tests from which they were derived. The first set was from the TSIM that was verified and validated by CRC and distributed with TSO C119B on December 4, 1998. The second set was an unverified version of TSIM provided by CRC that included the resolution to CP98.

10. Observed the loss of CRS coverage caused by CP98 in the original tests. Observed those Macro transitions being reacquired with the three new tests run in the updated version of TSIM.

11. Concluded that the new test suite of 309 tests regained full requirements coverage of the CRS.

12. Presented findings to RWG, which approved of the process followed and concurred with findings.

13. Received verification from the TCAS manufactures that they obtained the same results in their simulations and observed the reacquisition of CRS coverage with the three newly developed tests.

Attachment A
Lost Pseudocode Coverage

```
ROUTINE TWENTY_FIVE_FT_TRACKING

  IN (ZFLG, ZREPT, T)
  INOUT (pointer to N entry);

     access N entry;
     IF (N.INITCOMPLETED EQ $FALSE)
          THEN IF (ZFLG EQ $TRUE)
                    THEN  IF (CREDIBLE(N entry, T, ZREPT – N.Z) EQ $TRUE)
                              THEN PERFORM Rate_initialization;
          ELSE  ZDCHANGE = 0;
                IF (ZFLG EQ $TRUE)
                    THEN IF (CREDIBLE(N entry, T, ZREPT – N.ZSAVE) EQ $TRUE)
                              THEN  IF ((ZREPT EQ N.ZSAVE) AND
                                             (T – N.TTRAN GT PN.DTLONG))
                                        THEN PERFORM Level_track_update;
                                        ELSE    PERFORM Track_smoothing;
                                                IF (ZREPT NE N.ZSAVE)
                                                     THEN N.TTRAN = T;
                                                               N.ZSAVE = ZREPT;
                                   IF (N.ZD EQ 0)
                                        THEN N.CLASS = $LEVEL;
                                        ELSE  N.CLASS = $TREND;
                                   N.TDAT = T;
                              ELSE    CALL TRACK_COAST
                                        IN (pointer to N entry, T);
                    ELSE CALL TRACK_COAST
                              IN (pointer to N entry, T);
                PERFORM Rate_bound_update;
     N.TUPDT = T;

END TWENTY_FIVE_FT_TRACKING;
```

Attachment A
Lost Pseudocode Coverage

```
ROUTINE ONE_HUNDRED_FT_TRACKING

  IN (ZFLG, ZREPT, T)
  INOUT (pointer to N entry);

     access N entry;
     IF (ZFLG EQ $TRUE)
          THEN DZM = ZREPT – N.ZSAVE;
                    IF (CREDIBLE(N entry, T, DZM) EQ $TRUE)
                         THEN SET N.ALT_CREDIBLE;
                                   CLEAR OSTOSS;
                                   IF (DZM EQ 0)
                                        THEN PERFORM No_transition_update;
                                                  PERFORM No_transition_firmness;
                                        ELSE  PERFORM Transition_update;
                                   IF (OSTOSS EQ $FALSE)
                                        THEN N.TDAT = T;
                         ELSE      CLEAR N.ALT_CREDIBLE;
                                   CALL TRACK_COAST
                                        IN (pointer to N entry, T);
          ELSE CLEAR N.ALT_CREDIBLE;
                    CALL TRACK_COAST
                         IN (pointer to N entry, T);
     N.TUPDT = T;

END ONE_HUNDRED_FT_TRACKING;
```

```
ROUTINE AIRDATA_TRACKING

  IN (INIF, ZOK, ZIN, TIN, ZDIN)
  INOUT (pointer to OAT entry);

<This tracker is used to track own altitude data when the source of that data is an airdata
  computer or some other source of comparably finely quantized altitude data>

    IF (INIF EQ $TRUE)
        THEN create OAT entry;
                OAT.Z = ZIN;
                OAT.ZD = ZDIN;
                OAT.TDAT = TIN;
                OAT.TUPD = TIN;
                OAT.SOFT = P.MAXSOFT;
                SET OAT.ALT_CREDIBLE;
                Return address of OAT entry;

        ELSE    access OAT entry;
                ZPD = OAT.Z + OAT.ZD * (TIN – OAT.TUPD);
                IF (ZOK EQ $TRUE)
                    THEN IF (ABS(ZIN – ZPD) LE P.CREDZADC*OAT.SOFT)
                                THEN SET OAT.ALT_CREDIBLE;
                                     OAT.Z = ZPD + P.ALFAO * (ZIN – ZPD);
                                     OAT.ZD = OAT.ZD + P.BETAO * (ZIN – ZPD) /
                                          (TIN – OAT.TDAT);
                                     OAT.TDAT = TIN;
                                     OAT.SOFT = MAX(OAT.SOFT – 1, P.MINSOFT);
                         ELSE    CLEAR OAT.ALT_CREDIBLE;
                                 OAT.Z =ZPD;
                                 OAT.SOFT = MIN(OAT.SOFT + 1, P.MAXSOFT);
                    ELSE    CLEAR OAT.ALT_CREDIBLE;
                            OAT.Z =ZPD;
                            OAT.SOFT = MIN(OAT.SOFT + 1, P.MAXSOFT);
                OAT.TUPD = TIN;

END AIRDATA_TRACKING;
```

Attachment B
Lost CRS Coverage

Process	Line	CRS Section	Interface, State, Macro, or Function	Transition	Column or A
AIRDATA_TRACKING	1	N/A	Does_Not_Map	1	1
AIRDATA_TRACKING	2	4.76	Own_Fine_Tracked_Alt	1	1
AIRDATA_TRACKING	3	4.77	Own_Fine_Tracked_Alt_Rate	1	1
AIRDATA_TRACKING	4	4.51	Last_Own_Fine_Track_Update_Time	1	1
AIRDATA_TRACKING	5	3.57	Own_Altitude_Coast	1	dt
AIRDATA_TRACKING	5	4.76	Own_Fine_Tracked_Alt	1	dt
AIRDATA_TRACKING	5	4.77	Own_Fine_Tracked_Alt_Rate	1	dt
AIRDATA_TRACKING	6	3.57	Own_Altitude_Coast	1	SOFTNESS_
AIRDATA_TRACKING	6	2.1.18	Own_Tracker_Softness	1	1
AIRDATA_TRACKING	7	1.3.6	Own_Altitude_Credibility_Message	1	OWN_ALT_
AIRDATA_TRACKING	8	N/A	Does_Not_Map	1	1
AIRDATA_TRACKING	9	N/A	Does_Not_Map	1	1
AIRDATA_TRACKING	10	3.57	Own_Altitude_Coast	1	1
AIRDATA_TRACKING	10	3.57	Own_Altitude_Coast	1	dt
AIRDATA_TRACKING	10	3.57	Own_Altitude_Coast	1	PREDICTED
AIRDATA_TRACKING	10	4.76	Own_Fine_Tracked_Alt	1	dt
AIRDATA_TRACKING	10	4.76	Own_Fine_Tracked_Alt	1	ZP
AIRDATA_TRACKING	10	4.77	Own_Fine_Tracked_Alt_Rate	1	dt
AIRDATA_TRACKING	10	4.77	Own_Fine_Tracked_Alt_Rate	1	ZP
AIRDATA_TRACKING	11	1.3.6	Own_Altitude_Credibility_Message	1	OWN_ALT_
AIRDATA_TRACKING	12	4.76	Own_Fine_Tracked_Alt	1	1
AIRDATA_TRACKING	13	4.77	Own_Fine_Tracked_Alt_Rate	1	1
AIRDATA_TRACKING	13	4.77	Own_Fine_Tracked_Alt_Rate	1	CALCULAT
AIRDATA_TRACKING	14	4.51	Last_Own_Fine_Track_Update_Time	1	1
AIRDATA_TRACKING	15	3.57	Own_Altitude_Coast	1	SOFTNESS_
AIRDATA_TRACKING	15	2.1.18	Own_Tracker_Softness	3	1
AIRDATA_TRACKING	15	2.1.18	Own_Tracker_Softness	3	2
AIRDATA_TRACKING	16	1.3.6	Own_Altitude_Credibility_Message	1	OWN_ALT_
AIRDATA_TRACKING	17	3.57	Own_Altitude_Coast	1	1
AIRDATA_TRACKING	17	4.76	Own_Fine_Tracked_Alt	1	1
AIRDATA_TRACKING	18	3.57	Own_Altitude_Coast	1	SOFTNESS_
AIRDATA_TRACKING	18	2.1.18	Own_Tracker_Softness	2	1
AIRDATA_TRACKING	19	1.3.6	Own_Altitude_Credibility_Message	1	OWN_ALT_
AIRDATA_TRACKING	20	3.57	Own_Altitude_Coast	1	2
AIRDATA_TRACKING	20	4.76	Own_Fine_Tracked_Alt	1	1
AIRDATA_TRACKING	21	3.57	Own_Altitude_Coast	1	SOFTNESS_
AIRDATA_TRACKING	21	2.1.18	Own_Tracker_Softness	2	1
AIRDATA_TRACKING	22	3.57	Own_Altitude_Coast	1	dt
AIRDATA_TRACKING	22	4.76	Own_Fine_Tracked_Alt	1	dt
AIRDATA_TRACKING	22	4.77	Own_Fine_Tracked_Alt_Rate	1	dt

Attachment B
Lost CRS Coverage

Process	Line	CRS Section	Interface, State, Macro, or Function	Transition	Column or A
CREDIBLE	1	3.98	VT_25ft_Coast	1	2
CREDIBLE	2	3.99	VT_Credible_Report	1	1
CREDIBLE	3	3.92	VT_100ft_Coast	1	TDAT
CREDIBLE	3	3.92	VT_100ft_Coast	1	TSTART
CREDIBLE	3	3.98	VT_25ft_Coast	1	TDAT
CREDIBLE	3	3.98	VT_25ft_Coast	1	TSTART
CREDIBLE	3	3.99	VT_Credible_Report	1	2
CREDIBLE	3	3.99	VT_Credible_Report	1	DRT
CREDIBLE	4	3.92	VT_100ft_Coast	1	TDAT
CREDIBLE	4	3.92	VT_100ft_Coast	1	TSTART
CREDIBLE	4	3.92	VT_100ft_Coast	1	ZD
CREDIBLE	4	3.98	VT_25ft_Coast	1	TDAT
CREDIBLE	4	3.98	VT_25ft_Coast	1	TSTART
CREDIBLE	4	3.98	VT_25ft_Coast	1	ZD
CREDIBLE	4	3.99	VT_Credible_Report	1	3
CREDIBLE	4	3.99	VT_Credible_Report	1	DRT
ONE_HUNDRED_FT_TRACKING	1	N/A	Does_Not_Map	1	1
ONE_HUNDRED_FT_TRACKING	2	2.3.3.2	Bin_Direction	4	1
ONE_HUNDRED_FT_TRACKING	2	2.3.3.2	Bin_Direction	5	1
ONE_HUNDRED_FT_TRACKING	2	1.3.6	Own_Altitude_Credibility_Message	1	DZM
ONE_HUNDRED_FT_TRACKING	2	4.104	VT_100ft_Bins_Crossed	1	1
ONE_HUNDRED_FT_TRACKING	2	3.92	VT_100ft_Coast	1	DZM
ONE_HUNDRED_FT_TRACKING	2	3.93	VT_100ft_No_Transition	1	1
ONE_HUNDRED_FT_TRACKING	2	4.117	VT_100ft_Tracked_Alt_Rate	1	GUESS_TRA
ONE_HUNDRED_FT_TRACKING	2	4.118	VT_100ft_Tracked_Alt_Rate_Inner	1	DELTA_Z
ONE_HUNDRED_FT_TRACKING	2	4.119	VT_100ft_Tracked_Alt_Rate_Outer	1	DELTA_Z
ONE_HUNDRED_FT_TRACKING	2	3.96	VT_100ft_Transition	1	1
ONE_HUNDRED_FT_TRACKING	3	1.3.6	Own_Altitude_Credibility_Message	1	OWN_ALT_
ONE_HUNDRED_FT_TRACKING	4	3.94	VT_100ft_Spurious_Oscillation	1	1
ONE_HUNDRED_FT_TRACKING	4	3.94	VT_100ft_Spurious_Oscillation	1	2
ONE_HUNDRED_FT_TRACKING	5	N/A	Does_Not_Map	1	1
ONE_HUNDRED_FT_TRACKING	6	N/A	Does_Not_Map	1	1
ONE_HUNDRED_FT_TRACKING	7	N/A	Does_Not_Map	1	1
ONE_HUNDRED_FT_TRACKING	8	4.11	VT_100ft_Last_Alt_Report_Time	1	1
ONE_HUNDRED_FT_TRACKING	9	1.3.6	Own_Altitude_Credibility_Message	1	OWN_ALT_
ONE_HUNDRED_FT_TRACKING	10	3.92	VT_100ft_Coast	1	2
ONE_HUNDRED_FT_TRACKING	11	1.3.6	Own_Altitude_Credibility_Message	1	OWN_ALT_
ONE_HUNDRED_FT_TRACKING	12	3.92	VT_100ft_Coast	1	1
ONE_HUNDRED_FT_TRACKING	13	N/A	Does_Not_Map	1	1

Attachment B
Lost CRS Coverage

Process	Line	CRS Section	Interface, State, Macro, or Function	Transition	Column or A
TWENTY_FIVE_FT_TRACKING	1	N/A	Does_Not_Map	1	1
TWENTY_FIVE_FT_TRACKING	2	N/A	Does_Not_Map	1	1
TWENTY_FIVE_FT_TRACKING	3	4.127	VT_25ft_AB_Tracked_Alt_Accel	1	1
TWENTY_FIVE_FT_TRACKING	4	N/A	Does_Not_Map	1	1
TWENTY_FIVE_FT_TRACKING	5	N/A	Does_Not_Map	1	1
TWENTY_FIVE_FT_TRACKING	6	4.139	VT_25ft_Transition_Time	1	1
TWENTY_FIVE_FT_TRACKING	7	4.132	VT_25ft_Previous_Alt_Report	1	1
TWENTY_FIVE_FT_TRACKING	8	2.3.4.3	25ft_Bin_Transition_Status	4	1
TWENTY_FIVE_FT_TRACKING	9	2.3.4.3	25ft_Bin_Transition_Status	5	1
TWENTY_FIVE_FT_TRACKING	10	4.13	VT_25ft_Last_Alt_Report_Time	1	1
TWENTY_FIVE_FT_TRACKING	11	3.98	VT_25ft_Coast	1	2
TWENTY_FIVE_FT_TRACKING	11	3.98	VT_25ft_Coast	1	DZM
TWENTY_FIVE_FT_TRACKING	12	3.98	VT_25ft_Coast	1	1
TWENTY_FIVE_FT_TRACKING	13	N/A	Does_Not_Map	1	1
TWENTY_FIVE_FT_TRACKING	14	N/A	Does_Not_Map	1	1