Performance Analysis

Asiana 214 777-200ER

Enhanced Ground Proximity Warning System (EGPWS)

KSFO – July 06, 2013

November 20, 2013

Honeywell

EGPWS Modes Analyzed

- **Mode 1, Excessive Descent Rate**
- **Mode 2, Terrain Closure Rate**
- **Mode 3, Descent after Takeoff**
- **Mode 4, Unsafe Terrain Clearance**
- **Mode 5, Glideslope**
- **Mode 6, Advisory Callouts**
- **Mode 7, Windshear**
- **TCF and RFCF**
- **Terrain Alerting and Display (TAD)**

Asiana 214 B777-200ER accident at KSFO

- **NTSB DCA13MA120, 06 July 2013, – 3 Fatal**
  - **Crashed just short of Runway 28L during VFR approach**
  - **Glideslope for 28L out of service, no Glideslope input to EGPWS**
- **Preliminary information suggests there were no alerts issued by the EGPWS**
  - **EGPWS did activate advisory callouts**
    - Minimums-Minimums, 500, 200, 100, 50, 40, 30, 20, 10
- **FDR data 137 seconds before impact analyzed**
  - **EGPWS Flight History download has not been performed to date**
  - **Data shows:**
    - Gear down for duration of data sample (2550' AGL)
    - Flaps 5 at start of FDR date (2550' AGL, 177 knots)
    - Flaps 20 (1900' AGL, 175 knots)
    - Flaps 30 (1500' AGL, 168 knots)
    - See Google Earth graphic next page
    - Note discontinuity in Baro Altitude

EGPWS Unit Installed

- **MK V EGPWS**
  - **PN 965-0976-003-218-218**
  - **Terrain Database v467**
    - Released December 2012
    - v468 was available 16 May 2013

- **Assumptions in analysis:**
  - **EGPWS had direct GPS inputs**
    - Based on FMS Nav Mode word
  - **EGPWS in Approach Mode**
    - Based on phase of flight
  - **Actual K factor for TCF and RFCF is not known from FDR data but assumed to be at lower limit (highly accurate) for purpose of this analysis**
    - K factor determines how far from runway end TCF and RFCF protection begins

Mode 1, Excessive Descent Rate

- **Based on Terrain Clearance (radio altitude) and descent rate (IRS vertical speed)**

- **Sinkrate curve equation:**
  - Radio Altitude (feet) = -572 (feet) - 0.6035 * Altitude Rate (fpm)

- **No curve bias active for Steep Approach or Glideslope**
  - No Steep Approach switch in cockpit
  - No valid glideslope input

- **Aircraft did not penetrate Mode 1 curve**
  - See graph next page

Mode 1

ASIANA FLIGHT 214 - KSFO
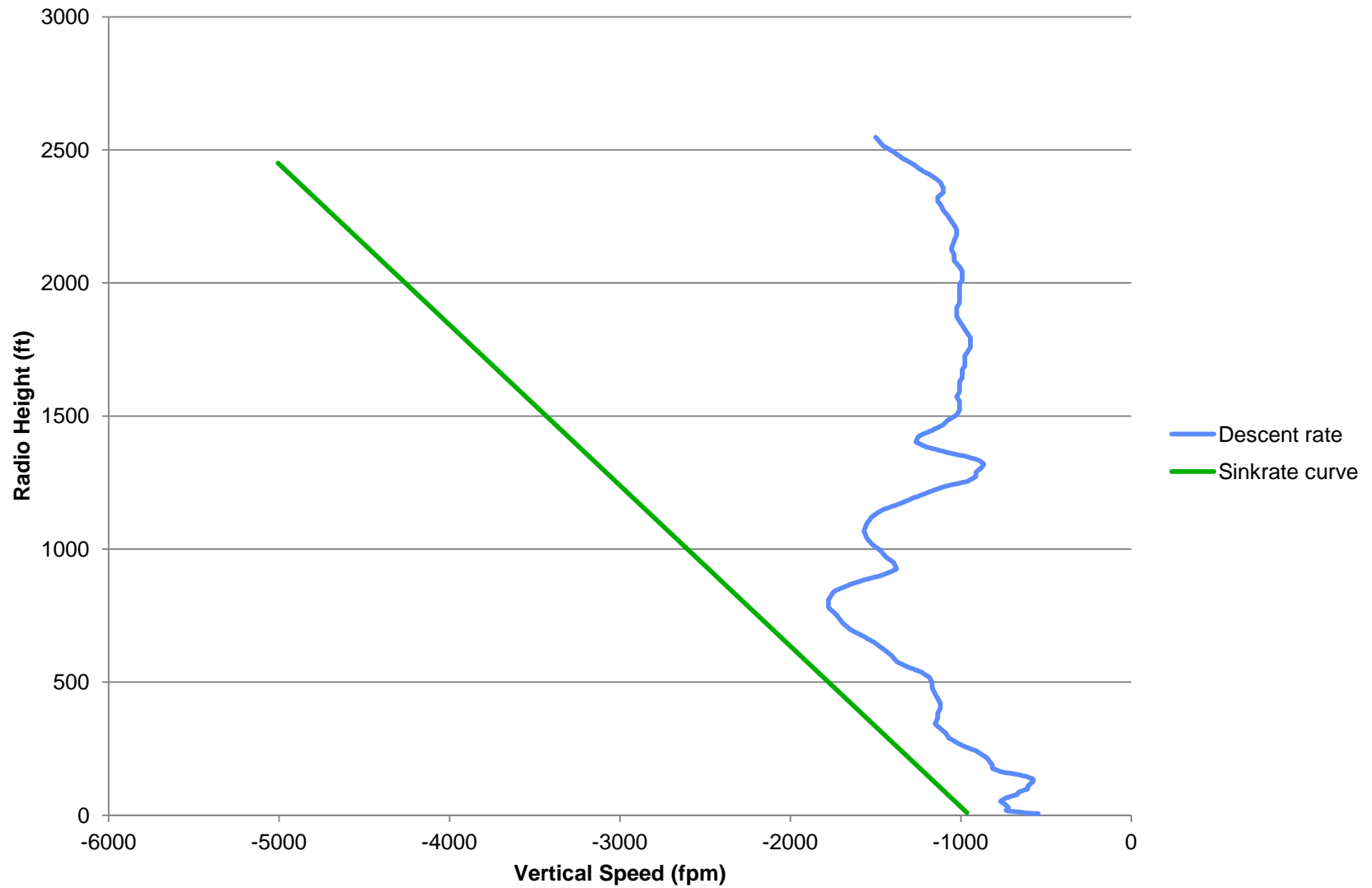
Mode 2, Terrain Closure Rate

- **Based on Terrain Clearance (radio altitude) and rate of change this signal (closure rate)**

- **Aircraft is flying over sea level water, so closure rate will mimic descent rate.**

- **EGPWS selects Mode 2B when less than 10 nm and less than 3500 feet vertically from destination runway**
  - **EGPWS was in Mode 2B for duration of FDR data**

- **Mode 2B ceiling is 789 feet radio altitude and requires closure rate in excess of 2000 feet per minute**
  - **Closure rate (vertical speed) did not exceed 1800 fpm**

- **Aircraft did not penetrate Mode 2 curve**

Mode 3, Descent after Takeoff

- **Active only when EGPWS is in Takeoff Mode**
  - Takeoff Mode = first 3 minutes after takeoff at normal climb rate or;
  - during go-around after raising gear or flaps
- **Aircraft flight does not meet takeoff/go-around criteria**
  - This algorithm was not active
  - No Mode 3 alert is expected on final approach

Mode 4A and 4B - Unsafe Terrain Clearance

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- **Mode 4A is active when gear is up**
  - When gear is down, Mode 4A is deactivated and Mode 4B is activated.
  - Gear is down for duration of FDR data, so Mode 4B is active

- **When flaps are not in landing configuration, Mode 4B provides two possible alerts at 245 feet AGL**
  - Too Low Flap if CAS < 159 knots
  - Too Low Terrain if CAS > 159 knots

- **FDR data shows flaps were in landing configuration (Flaps 30) at 1500' AGL, therefore aircraft did not penetrate Mode 4A or Mode 4B curve**

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Mode 4C - Unsafe Terrain Clearance

- **Active during Takeoff only**
- **Alert designed to cover cases where the aircraft may be climbing, but the terrain below the aircraft is rising faster**
- **Aircraft flight does not meet takeoff/go-around criteria**
  - **This algorithm was not active**
  - **No Mode 4C alert is expected on final approach**

Mode 5, Descent Below Glideslope

- **Mode 5 provides alerts when aircraft is receiving valid Glideslope deviation and more than 1.3 dots fly up**

- **No valid Glideslope signal was received as the glideslope for 28L was out of service**

- **Mode 5 alerting was not active**

Mode 6, Advisory Alerts

- **3 Types of callouts are provided**
  - Altitude Awareness ("500", "200", etc)
  - "Minimums"
  - "Bank Angle"

- **Bank Angle alert requires roll angle > 35 degrees**
  - FDR data peak roll angle was < 3.5 degrees
  - No bank angle alert was expected

- **CVR did record expected Minimums and Altitude Awareness callouts**
  - Gives confidence radio altimeter inputs are responding correctly on approach

Mode 7, Windshear

- **EGPWS provides reactive windshear alerting to compliment predictive windshear alerting provided by Weather Radar system.**

- **It is noted:**
  - Preliminary information suggests that the Predictive Windshear system did not activate
  - No reports of ground based Windshear detection activation
  - No reports of convective activity in the region at the time of the approach

- **Therefore no detailed analysis of Windshear algorithm was performed**

Terrain Clearance Floor (TCF)

- **TCF provides premature descent alert**
  - **Alert curve is set well below 3 degree approach profile**
- **TCF based on terrain clearance (radio altitude)**
- **TCF alerts begin $\geq$0.25nm from runway end**
  - **Distance (K factor) is function of position uncertainty and runway data quality, and can be greater than 0.25nm**
    - KSFO is RAAS enabled, therefore has the best runway data quality
    - This analysis assumes K=0.25nm, typical with GPS inputs
  - **Rising 200 feet/nm for first 1.0 nm, then 200/3 feet nm for next 3.0 nm, leveling off at 400 feet until more than 12 nm from runway end**
- **TCF graph shown later in analysis**
  - **As aircraft is flying over sea level water, radio altitude should approximate aircraft elevation**

Runway Field Clearance Floor (RFCF)

- **RFCF provides earlier alerts than TCF for airports that are higher than nearby terrain**
  - **Not the case at KSFO, RFCF curve mostly below TCF curve**
- **RFCF is based on height above field**
  - **Geometric/MSL Altitude (internal calculation) – Runway altitude**
- **RFCF alerts begin $\geq$0.5nm from runway end**
  - **Distance (K factor) is function of position uncertainty, runway data quality, altitude uncertainty and can be greater than 0.5nm**
    - KSFO is RAAS enabled, therefore has the best runway data quality
    - This analysis assumes K=0.5nm, typical with GPS inputs
  - **Rising to 300 feet above field at 2.0 nm from runway end and maintaining this height to 5.0 nm from runway end**
- **As shown on next page, the aircraft did not penetrate TCF or RFCF curve, even with best possible K factor**

TCF and RFCF

ASIANA FLIGHT 214 - KSFO
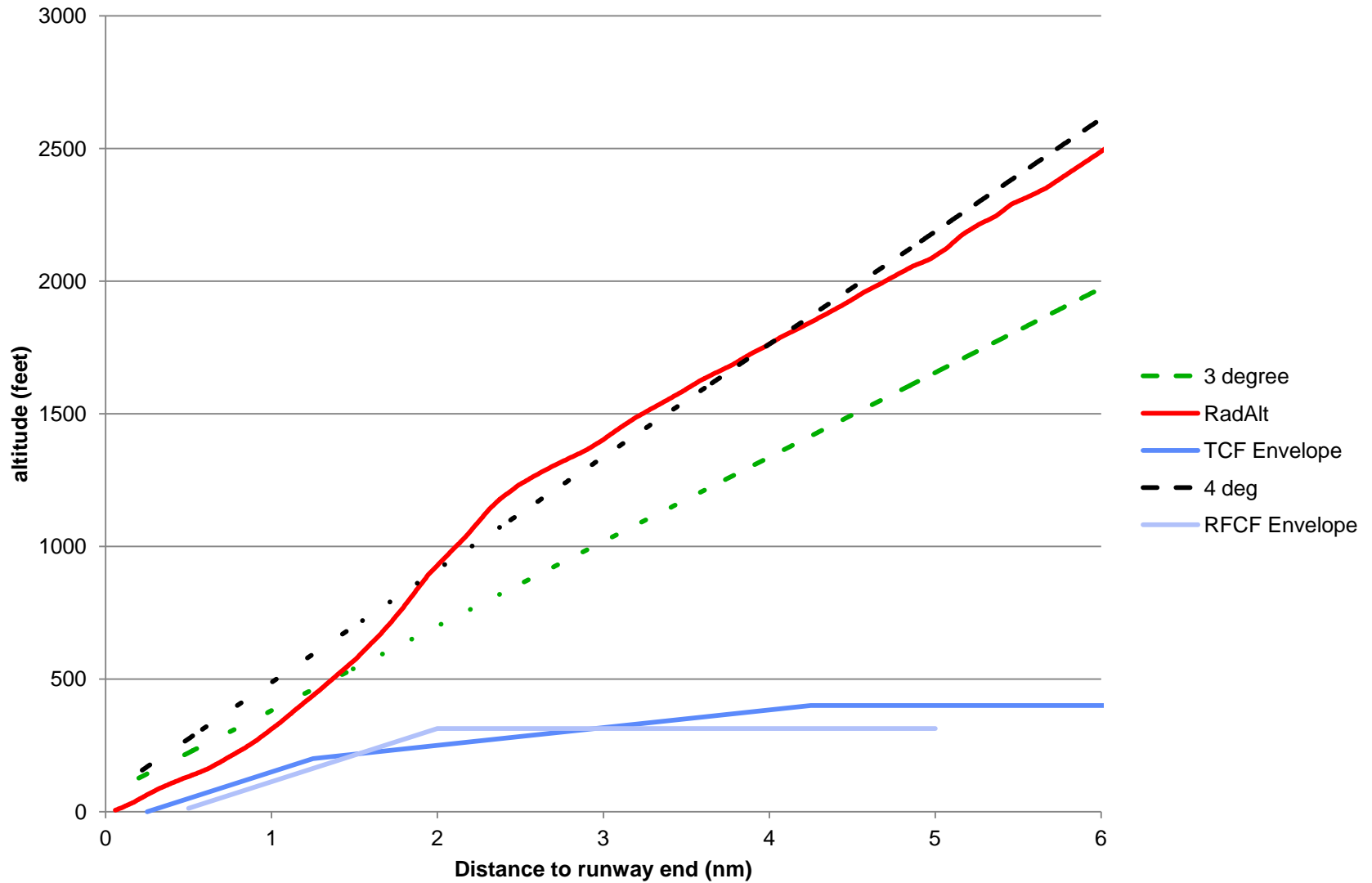
Terrain Alerting and Display

- **When less than 1.6 nm of runway end, only terrain or obstacles more than 200 feet above runway elevation can trigger Terrain Look-Ahead alert**
  - Final approach was over sea level water, so no terrain or obstacles meet this criteria
  - TCF and RFCF provide primary protection near runway
- **Therefore no analysis of Terrain Look Ahead was deemed necessary or performed**

Terrain Database and Runway 28L

- **Runway 28L recently displaced by 300 feet**

- **Installed database v467 does not include any displaced threshold for 28L**
  - **TAD/TCF/RFCF do not use displaced threshold data**
    - ◆ Curve origin is paved end of runway
  - **The paved end of 28L has not changed**
  - **Therefore the data in v467 remains valid and correct for TAD/TCF/RFCF**
  - **Honeywell does use DT in Runway Awareness and Advisory System (RAAS) calculations, and will update DT data in v470 (December 2013). RAAS is an optional feature to which Asiana does not subscribe.**