Parachute Mishap Investigation Training

Rich Greenwood

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Instructor Bio

Rich Greenwood

- USAF Aircraft / Parachute accident investigator
- 31 year with Pratt & Whitney Military Flight Safety
- Commercial Pilot with Instrument and Multi engine ratings
- FAA Master Parachute Rigger with Chest, Seat and Back Ratings
- A&P/IA
- FAA Designated Parachute Rigger Examiner
- USPA Tandem / Static line / AFF instructor with 3600 Jumps
- USHPA P4 Expert Paraglider Pilot

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Students

- Is there anyone in the in the audience who has investigated a parachute mishap?

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Philosophy

- Occam's Razor "*Among competing hypotheses, the one with the fewest assumptions should be selected.*"
- If something doesn't make sense, know that it really *does* make sense, you just haven't connected the dots yet.
- Minor loose ends are sometimes the key to connecting the dots. Make every effort to understand "loose ends".

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Philosophy

- Finally, *"Just because nobody complains doesn't mean all parachutes are perfect"*

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Questions?

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Accident Types

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Accident Types

- Jumper / Aircraft entanglement
- Jumper in Tow
- Jumper / Aircraft collisions
- Freefall mid air collision
- Malfunctions
- Post opening collisions
- No pull / low pull
- Low turns

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Jumper/Aircraft Entanglement

- Result of accidental main or reserve canopy deployment while the jumper is still in or climbing out of the aircraft
  - Ripcord snag
  - Pilot chute snag
  - Bumping and dislodging closing pins during climb out
  - AAD fire
- Can also be jumper equipment catching on part of the aircraft
- Typically catches on horizontal stabilizer
  - Has resulted in loss of aircraft

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Jumper/Aircraft Entanglement

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Jumper in Tow

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Jumper/Aircraft Collisions

- May be with the jump aircraft but has also been with other non participating aircraft
  - In any case, it usually does not end well
  - There is at least one recorded incident where the jumper lived with minor injuries and all four people in the aircraft perished

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Jumper/Aircraft Collisions

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Freefall Mid Air Collision

- Jumper to Jumper contact during freefall prior to canopy deployment
- Closing speed during a full track can be in excess of 120 MPH horizontally
- Jumpers also live under the VFR see and avoid concept

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Freefall Mid Air Collision

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Malfunctions

- Any time a parachute component part does not function properly, suffers a structural failure or is packed / operated improperly
  - May be a minor land able malfunction such as a broken suspension line
  - May require a release of the main parachute and deployment of the reserve
  - May not be survivable regardless of jumper actions (Harness failure?)

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Malfunctions

- High Speed
  - Total Malfunction (Nothing Deployed)
    - Pilot chute spring weak (ripcord)
    - Compatibility of container/canopy
    - Ripcord or Static Line failure
    - Bridle/pin failure (hand deploy)
    - Misrouted bridle
    - Closing loop length / material
    - Compatibility of container / canopy
    - AAD malfunction

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Malfunctions

- High Speed (cont)
  - Pilot chute in tow (horseshoe)
    - Check permeability of pilot chute, design, centerline size
    - Snag points (boots)
    - Collapsing system
      - Kill line Shrinkage
      - Bungee/F-111 type
  - Bag strip / line dump
    - Locking stow retention/condition/materials
    - Pilot chute size (too big)
    - Canopy/Bag size compatibility

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High Speed Malfunction

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High Speed Malfunction

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Burble

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Line Dump

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Malfunctions

- Low Speed
  - Line overs
  - Broken lines / line attachments
  - Pressure Knots
  - Tears
  - Pilotchute entanglements
  - Brake hang-ups / inadvertent release
  - Slider problems

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Malfunctions

- Dual deployment
  - Usually result of low main deployment / AAD fire
    - Check for cut reserve closing loop
    - Download any available recorders
      - AAD, audible or visual altimeters
  - Also can be result of reserve deployment when a jumper experiences a pilot chute in tow
    - Open reserve container relieves pressure on main and allows deployment
  - Miss-assembly
  - Inspect harness for riser damage

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Dual Square

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Dual Square

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Opening and Post Opening Collisions

- Freefalling jumper colliding with a another jumper during the deployment sequence
- Jumpers colliding during or shortly after both deploy
- Jumpers colliding / entangling during intentional canopy formation flight
- Jumpers colliding while approaching the DZ

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Post Opening Collisions

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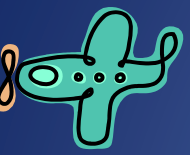
Exit Order Issues
Jumper Trajectory No Wind



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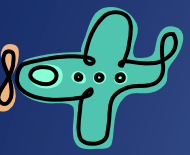
Exit Order Issues
Jumper Trajectory - Wind



Wind

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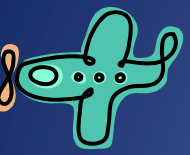
Exit Order Issues
No wind



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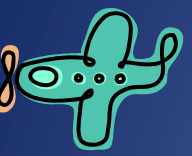
Exit Order Issues
Wind speed = ½ Airspeed



Wind

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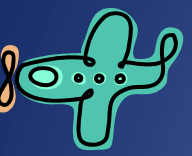
Exit Order Issues
Wind Speed =3/4 Airspeed



Wind

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Exit Order Issues
Wind Speed Equals Airspeed

Wind

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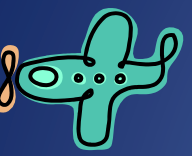
Wind speed = ½ Airspeed
Second Jumper Falls Slower Than First



Wind

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Exit Order Rules

- The higher the winds aloft, the more time is needed between exits
- Slower falling jumpers go first
- Faster falling jumpers go next
- Jumpers opening high go last

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Post Opening Collisions

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No Pull/Low Pull

- No attempted deployment of the main or reserve parachute or deployment is initiated below a useful altitude
  - Medical issues (including drugs)
  - Suicide
  - Temporal Distortion/Distraction
    - Jumper spends time focusing on one issue and looses track of time/altitude (Eastern Airlines Flight 401)

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Low Turn (CFIT)

- Jumper turns canopy at a low altitude and impacts the ground before recovering to level flight
  - Usually a misjudged turn during a high performance landing maneuver. Can be exacerbated by:
    - High wing loadings
    - Inexperience
  - Dropped toggle
  - Turbulence
  - Avoidance maneuver

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On scene data collection

- Who has authority?
- First responders will have disturbed gear
- Secure witness statements, including other jumpers on load, first responders and pilot(s)
- Weather (Weather Underground has good historical data)
- Secure all gear including
  - data recorders (Altimeters, audibles, cameras, GPS units)
  - main/reserve/harness/AADs
    - If possible get harness adjustment measurements before removal
  - Account for all equipment (Four Corners of the Aircraft)
    - Cut-away main, reserve pilot chute/free bag, ripcords and cutaway handle
  - Clothing including gloves, if worn

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On scene data collection (cont)

- Packing data card
- Manifests records (all jumps jumper has made, not just day of jump)
- Jumper logbook if available
- Photo document accident site
  - Impact scars

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Questions?

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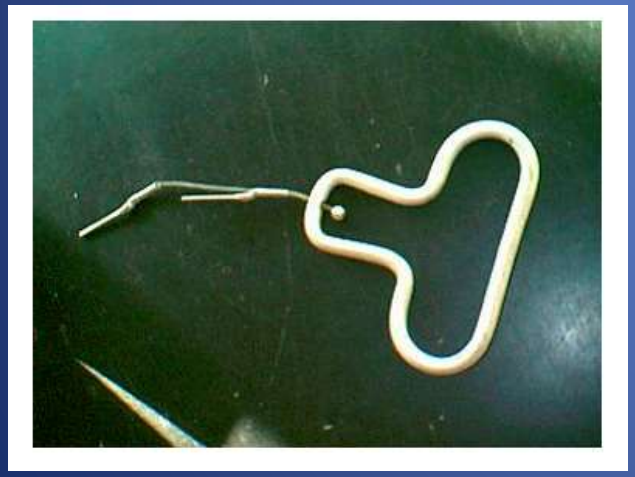
Parachute Component Parts



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Typical components of a premeditated freefall parachute system

- Four main components
  - Harness and container system
  - Main Parachute
  - Reserve Parachute
  - Automatic Activation Device
- In the United States, for civilian use, reserve and harness and container system must be TSO'd (Technical Standard Order C-23x)

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Parachute Component Parts
Typical "PiggyBack" System

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Harness and Container Systems

- Piggy back style
  - Both parachutes on back; main on bottom, reserve on top
  - Type VII, VIII or Type XIII nylon webbing harness and Cordura container
  - Includes main and reserve deployment bags, pilot chutes, bridles, ripcords, steering toggles, cut-a-way handle and risers

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Main Parachute

- Ram air inflated
- Zero porosity or “F111” material
- Various types of suspension lines
- Deployment bag and slider controlled openings
- Ripcord or hand deployed pilot chute activated

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Main Parachute

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Reserve Parachute

- Ram air inflated
- “F111” material
- Dacron or Spectra suspension lines
- Deployment bag and slider controlled openings
- Ripcord/RSL/MARD/AAD activated

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AAD

- Automatic Activation Device
- Uses air pressure to determine jumper's altitude and vertical speed
- Pyrotechnic cutter cuts reserve closing loop when both altitude and speed triggers are met
- Non Volatile Memory records data on jumps and activations
  - Some also log jumps and can be downloaded in the field

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Sub Components

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Activation Handles

- Main Deployment System
  - Hand Deploy (Two Types)
  - Ripcord and spring loaded pilotchute
  - Static line
- Reserve Ripcord
  - Reserve Static Line/Main Assisted Reserve Deployment activation
  - Ripcord
- Cutaway Handle
  - Cable length for proper RSL activation

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Pilotchutes

Hand Deploy

- Hand Deploy
- Used only on Mains

Spring Loaded

- Ripcord deployed
- Used on mains and reserves

Tandem Drogue

- Used on Tandem systems
- Staged Deployment

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Deployment Bags

Main Deployment Bag
- Attached to canopy
- Uses rubber bands for line stows

Reserve Deployment Bag
- Not Attached to canopy
- Free Stowed Lines

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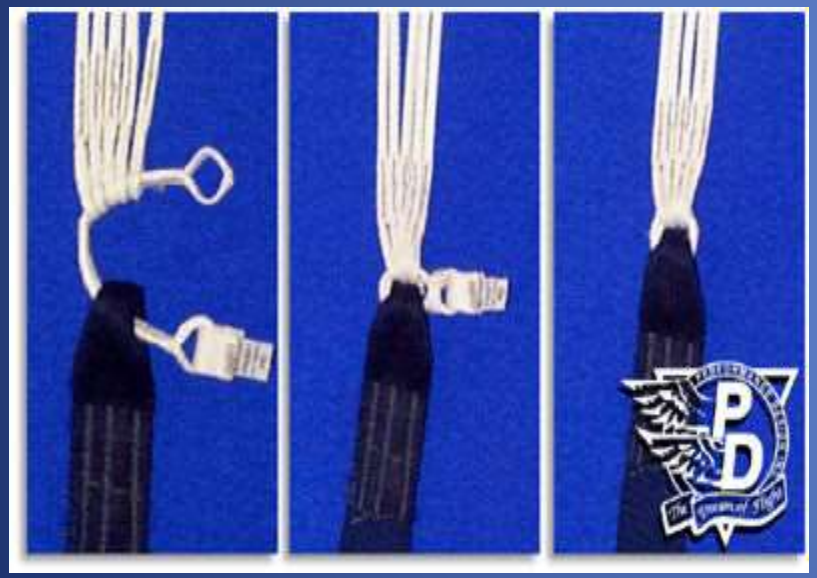
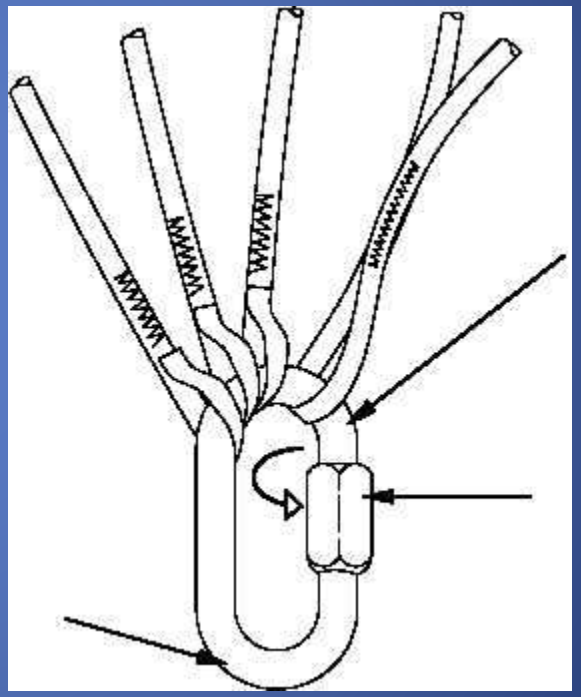
Connector links

- Soft links (Slinks)



- Metal Screw links



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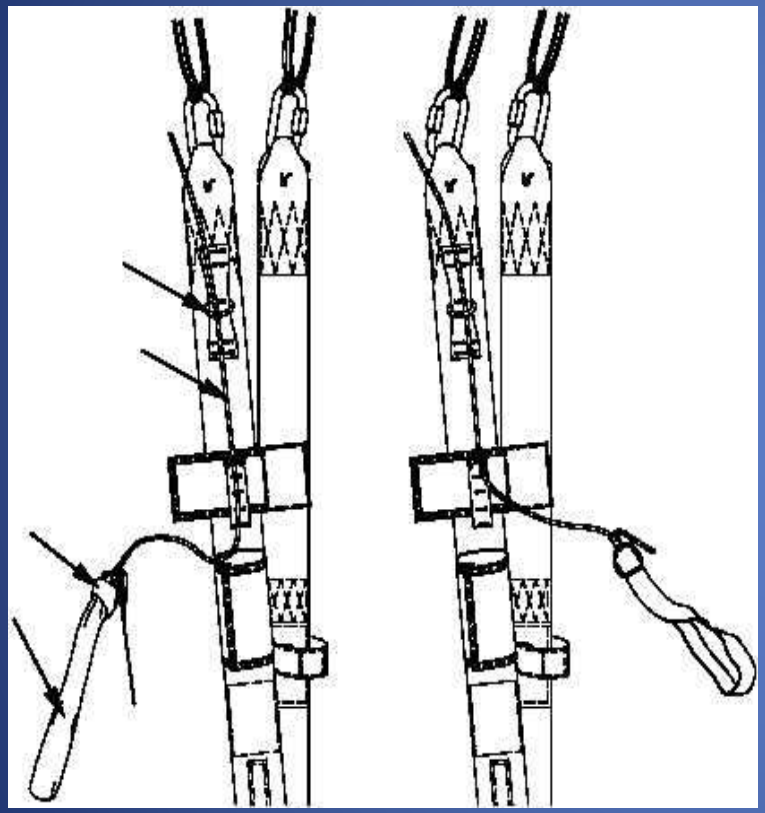
Risers



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3 Ring Release System

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RSL and MARD

- RSL - Reserve Static Line
  - Uses cut-a-way main parachute to activate reserve parachute
  - Lanyard hooked to main riser on one end and reserve ripcord/pin on the other
- MARD – Main Activated Reserve Deployment
  - Still uses RSL to pull reserve pin but then also uses cut-a-way main parachute as a pilot chute for reserve parachute

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MARD System

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Personal Components

- Visual Altimeters
  - Analog and digital
  - Some have NVM and are field downloadable
- Audible Altimeters
  - Worn in helmet and gives a loud beeping noise at jumper preselected altitudes
  - Most have field downloadable NVM
- Helmets
- Jumpsuit

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Ancillary Components (and potential snag hazards)

- Cameras
- Goggles
- Gloves
- Boots
- Rucksacks
- Weapons
- O2 Systems
- Navigation/Communication systems
- Lights for night jumps
- Smoke brackets
- Dive gear

Items that have snagged and led to serious injuries or fatalities

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Questions?

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Case Studies

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Case Studies

- Each of these case studies is a synopsis of the actual reports
- They are presented for educational purposes only
- They are shortened for time constraints and do not present all aspects of the investigation
- They are designed to give the investigator not familiar with parachute investigations an idea of the types of data available and the analysis techniques

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Incident #1
No Pull

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Witness Reports

- Experienced jumper solo freefall from 12,500 AGL
- Victim elected to exit last of 8 jumpers from a Cessna 208
- Fellow jumpers reported victim's gear appeared to be worn and adjusted correctly with all handles properly stowed
- Shortly after pilot reported jumpers away, an experienced jumper reported seeing a reserve parachute open to the north of the airfield
- The brakes of the reserve parachute appeared to be stowed

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Investigator notes upon arrival at site

- Investigators made their way to where the parachute landed and found:
  - Harness and container and open reserve were laying face down in the field
  - The victim was NOT in the harness or near the scene
  - Main parachute was still in the container and pilotchute stowed in its pouch
  - Reserve parachute deployed
    - Brakes still stowed
    - Slider only halfway down to the line cascades
  - Cut-a-way and reserve ripcord handles in place
  - Chest strap undone
  - Leg straps still in buckles but free ends un-stowed from their elastic keepers
  - AAD appeared to have fired and cut the reserve closing loop
  - No footsteps noted leading to or from the site

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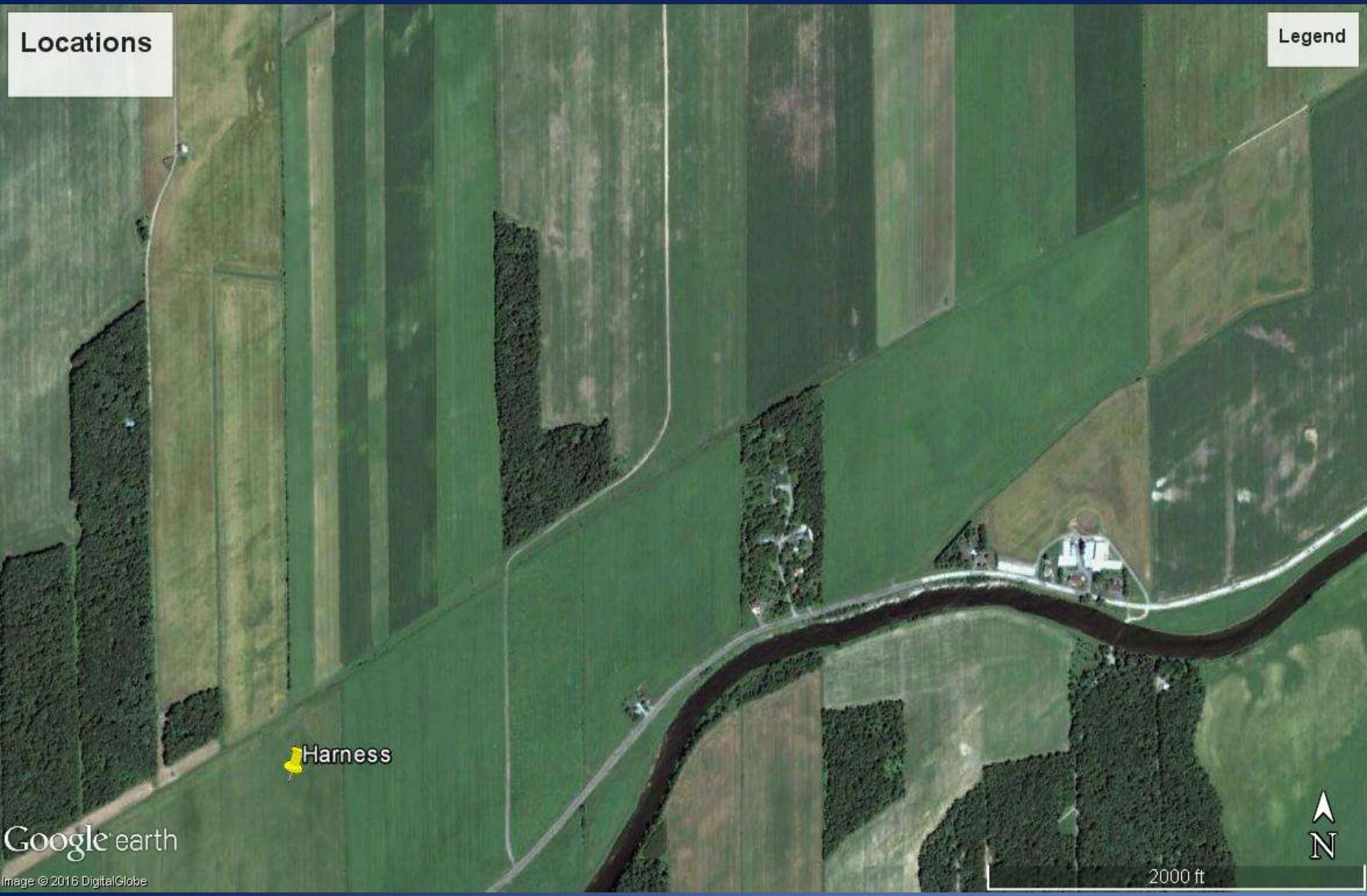

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Investigator notes

- 700 Meters to the NE of the harness the investigators found the reserve freebag and pilotchute in a tree

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Investigator notes

- 1480 Meters to the NE of the harness the investigators find the lifeless victim
  - Victim was laying on his back
  - Blood coming from his ears
  - Body seemed “Broken all over”
  - No helmet

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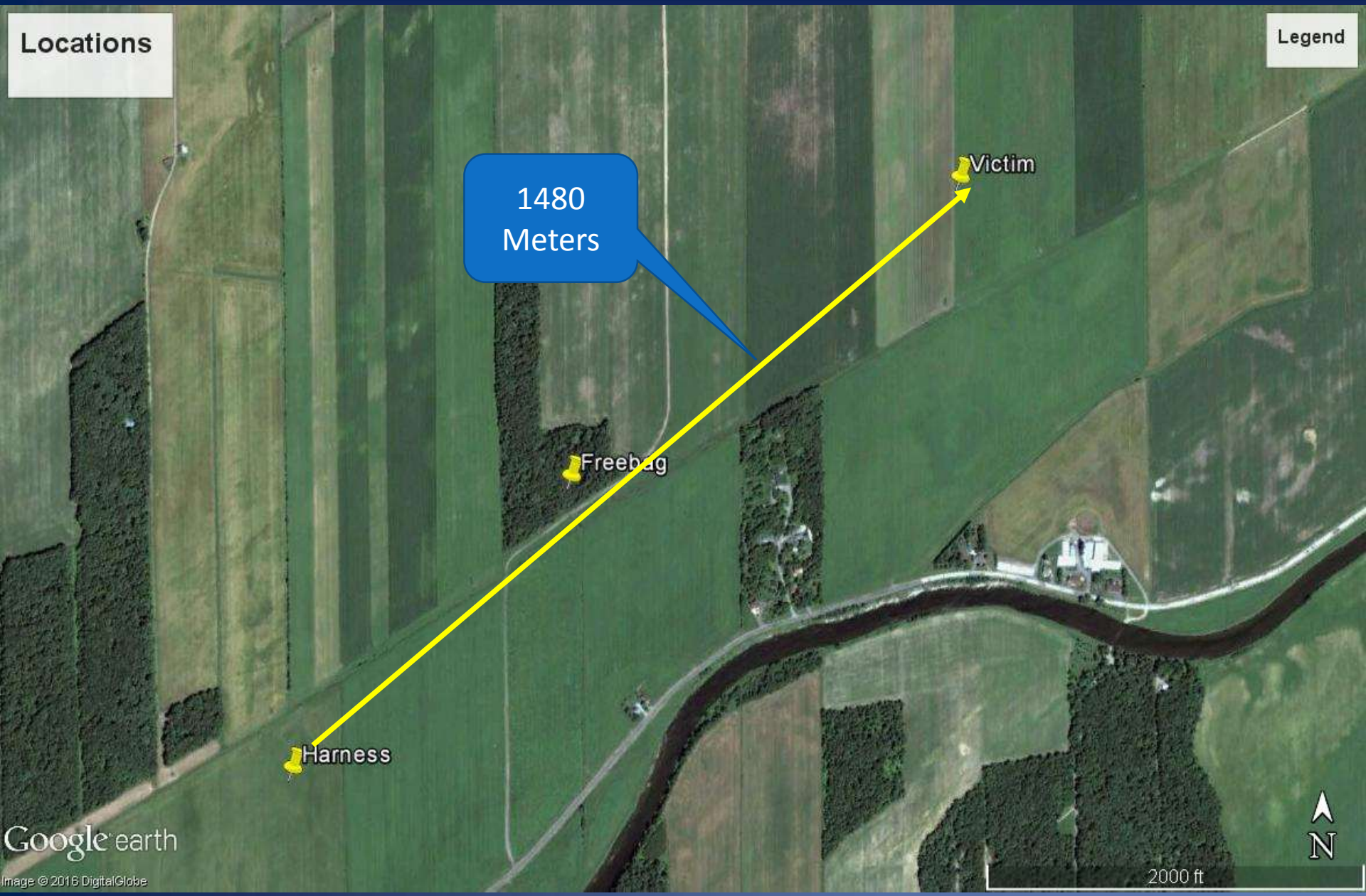

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Investigator notes

- Helmet was found approximately 100 Meters south of the victim
  - Helmet was cracked but not smashed
  - Helmet strap buckle was undone

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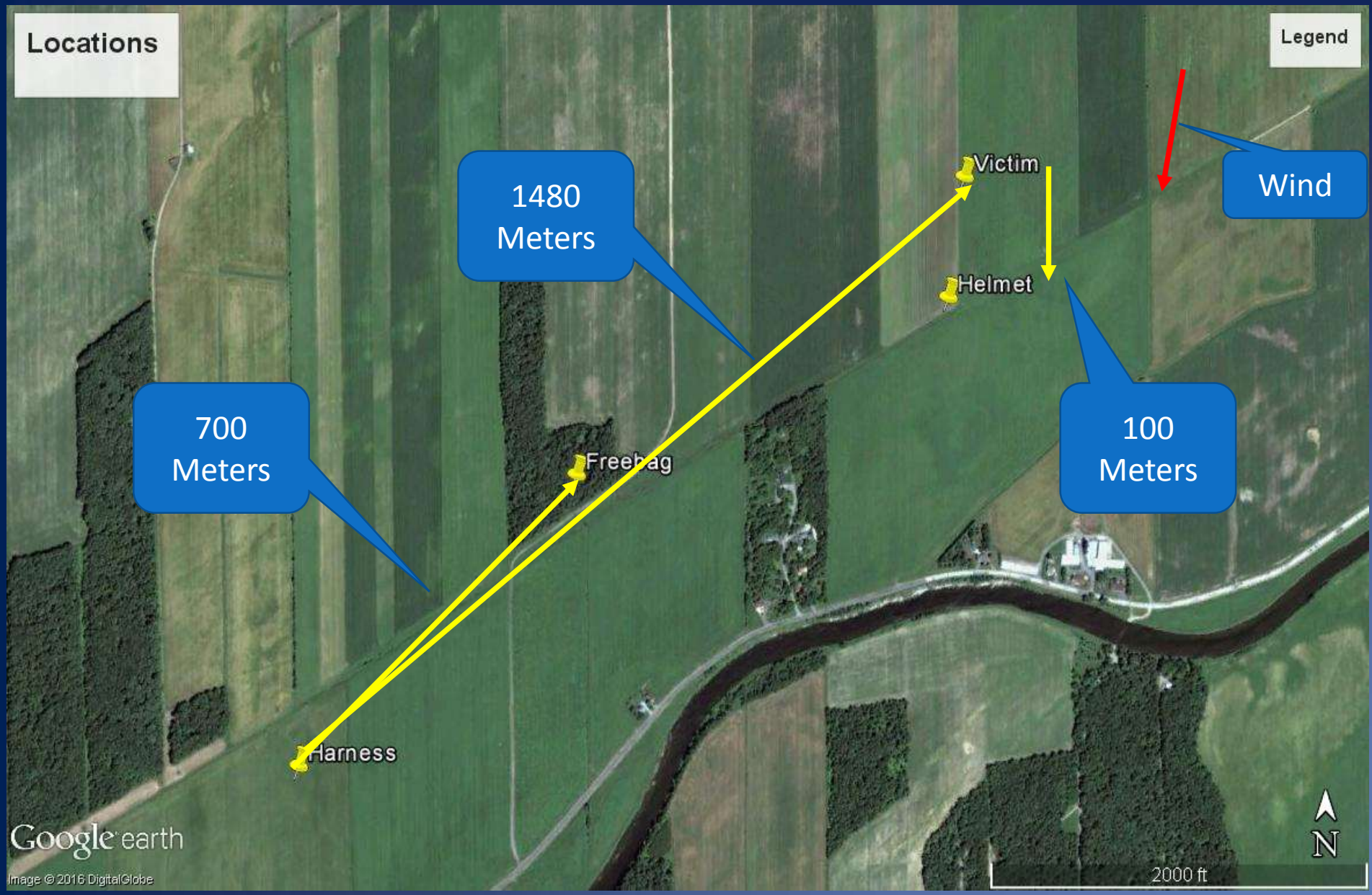

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Surface Wind Report

Time	Temp °C	Dew Point Temp °C	Rel Hum %	Wind Dir 10's deg	Wind Spd km/h	Visibility km	Stn Press kPa	Hmdx	Wind Chill	Weather
00:00	2.8	2.5	98	5	4		100.27			NA
01:00	0.8	0.6	99		0		100.24			NA
02:00	0.2	0.1	99	7	2		100.31			NA
03:00	1.2	1.1	99	35	2		100.34			NA
04:00	1.1	1.0	99	3	4		100.41			NA
05:00	1.0	0.9	99	5	7		100.49			NA
06:00	1.9	1.8	99	4	4		100.56			NA
07:00	5.7	5.5	99	2	6		100.61			NA
08:00	9.4	5.0	74	1	11		100.61			NA
09:00	11.9	4.2	59	1	13		100.60			NA
10:00	13.4	3.4	51	36	9		100.56			NA
11:00	14.4	2.7	45	36	19		100.54			NA
12:00	14.7	3.0	45	1	13		100.51			NA
13:00	14.9	3.2	45	2	13		100.52			NA
14:00	14.8	3.0	45	2	13		100.50			NA
15:00	15.0	3.1	45	1	15		100.51			NA
16:00	15.1	2.1	41	36	13		100.54			NA
17:00	14.6	2.5	44	36	11		100.56			NA
18:00										
19:00	12.2	5.0	61	1	7		100.65			NA
20:00	11.6	5.2	65	34	9		100.70			NA
21:00	10.9	5.2	68	35	7		100.74			NA
22:00	9.9	5.4	74	4	6		100.74			NA
23:00	9.8	4.6	70	1	7		100.75			NA

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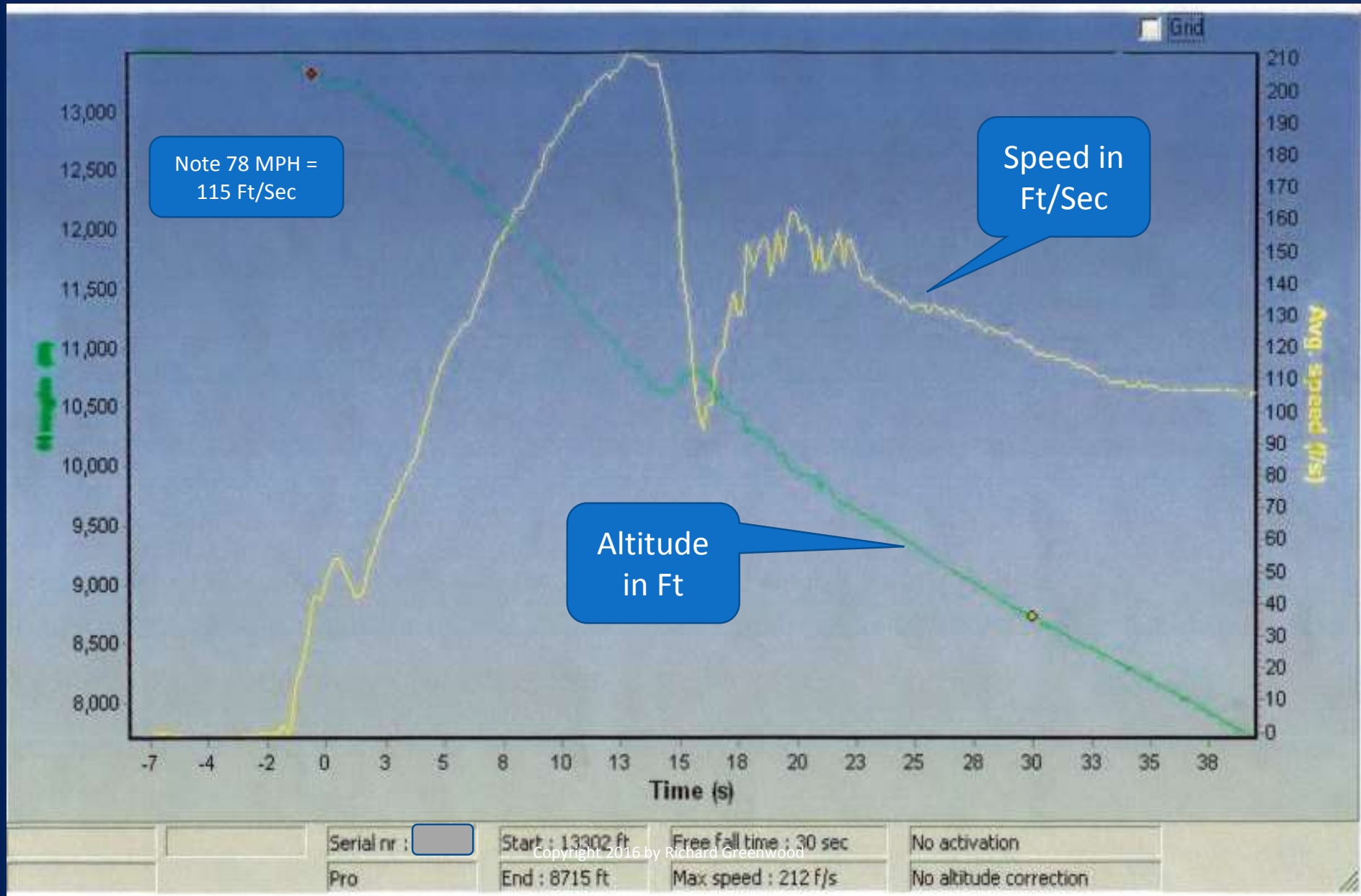
AAD Data – Second to last Jump



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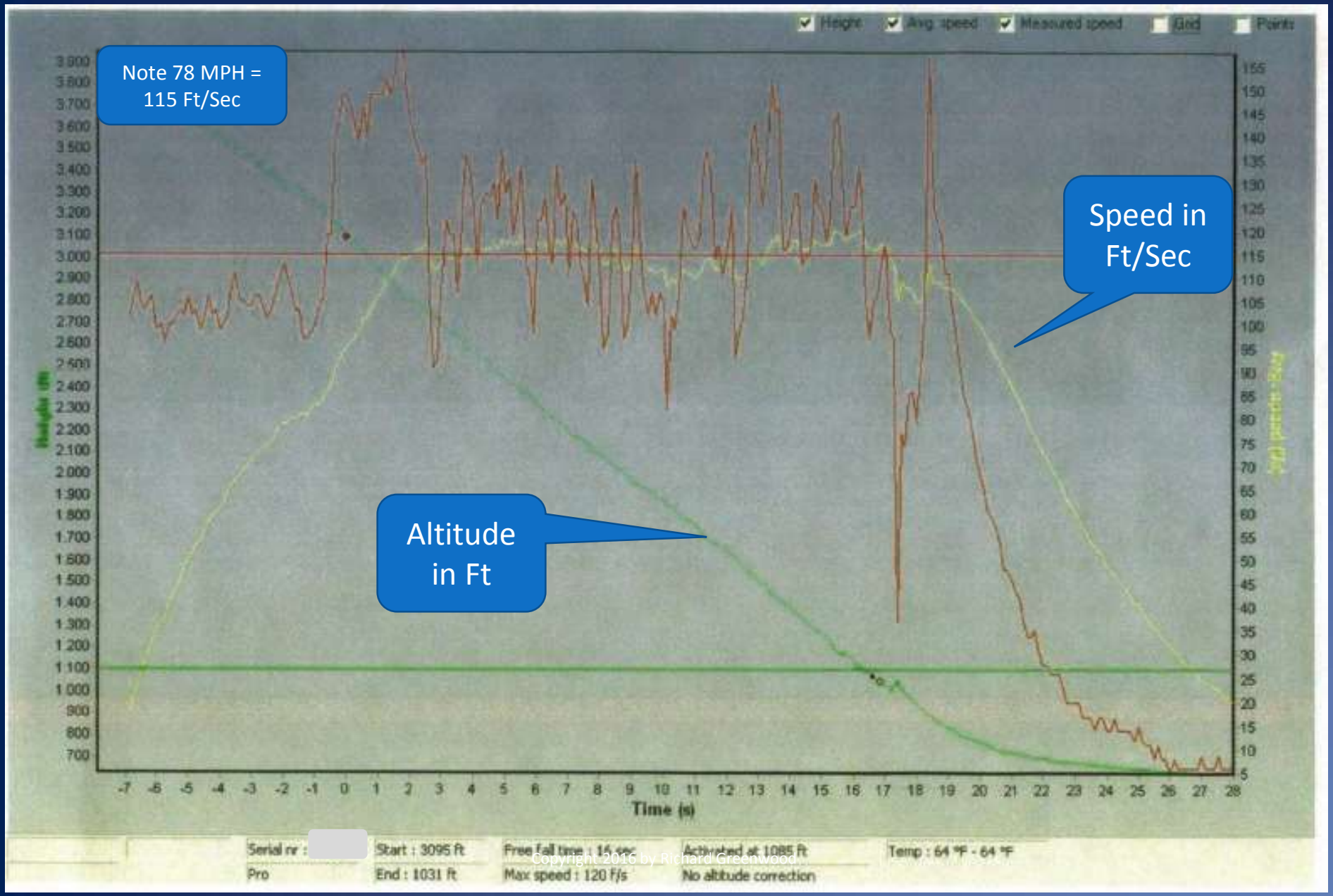
AAD Data –Last Jump



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Conclusions

- After exit the jumper removed his chest strap, loosened his leg straps and slipped out of his harness. It was not conclusively determined when he removed his helmet
  - These movements most likely resulted in an unstable body position and the higher than normal freefall speed
  - After removing his gear the freefalling gear decelerated to a lower than normal freefall speed, varying to just above and just below the AAD activation speed
  - After dropping below AAD activation speed the AAD determined the freefall was over (8715 Ft AGL) and stopped recording data 12 seconds later

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Conclusions

- At approximately 3095 Ft AGL the gear accelerated to above AAD activation speed and the ADD determined another jump had started and began recording
- The gear stayed above AAD activation speed until it passed AAD activation altitude at 1085 feet at which time the AAD fired, activating the reserve parachute
- Last recorded descent speed of the gear after reserve opening was ~6 Ft/Sec, well below a normal canopy descent speed of ~16 Ft/Sec

- Cause of death was determined to be suicide

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Incident #2
No Pull

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No Pull Incident

- Scenario
  - Freefall student on a solo jump from 4000 meters AGL
  - Student had 20 previous successful jumps
  - Witness reports of seeing student in freefall, face to earth at approximately 250-300 meters with a slight rotation. At 100 meters student disappeared behind the trees with no indication of a canopy deployment
  - Student impacted the ground approximately 850 meters from the jump manifest and suffered fatal injuries
  - Impact analysis showed student hit with slight forward velocity
  - Main pilotchute was found in the students right hand
  - Autopsy showed massive blunt force trauma and toxicology tests were negative.

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No Pull Incident

No Pull Incident

No Pull Incident

No Pull Incident

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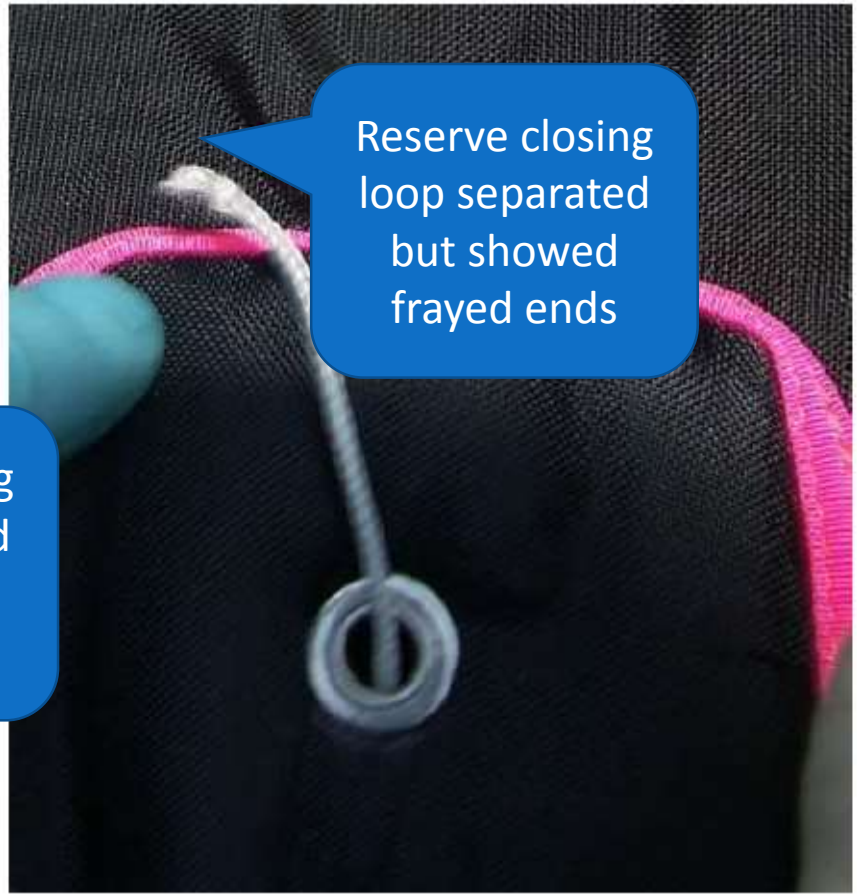
No Pull Incident



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No Pull Incident

- Tests were done relating to pack volume and compatibility of components which could have restricted deployment of reserve parachute. All components were deemed to be compatible.
  - No requirements for closing loop length was given by the manufacturer, however tests conducted with closing loops from 119 mm (extremely tight) to 210 mm (extremely loose) showed no adverse operation of the reserve activation system
- Inspection of the reserve canopy showed it appeared to have been packed properly with respect to line continuity and folding of the canopy material
- Inspection of the main canopy determined no discrepancies with respect to its packing instructions
- Reserve pilotchute spring pressure exceeded AAD manufactures minimum 5KG compression requirement
- Examination of instructor and rigger records found both to be trained, current and qualified for their duties
- The condition of the partially deployed reserve parachute and bridal entanglement were found to be consistent with other similar incidents where the reserve “bounced” out of the container on impact

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No Pull Incident

- The investigation then centered on the frayed reserve closing loop and the AAD cutter
- Test were performed on the same system using a AAD cutter of the same date numbered batch (Jan 07) as the incident cutter
- Reserve was packed with a nominal length closing loop (140mm) and the cutter was activated

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No Pull Incident

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No Pull Incident

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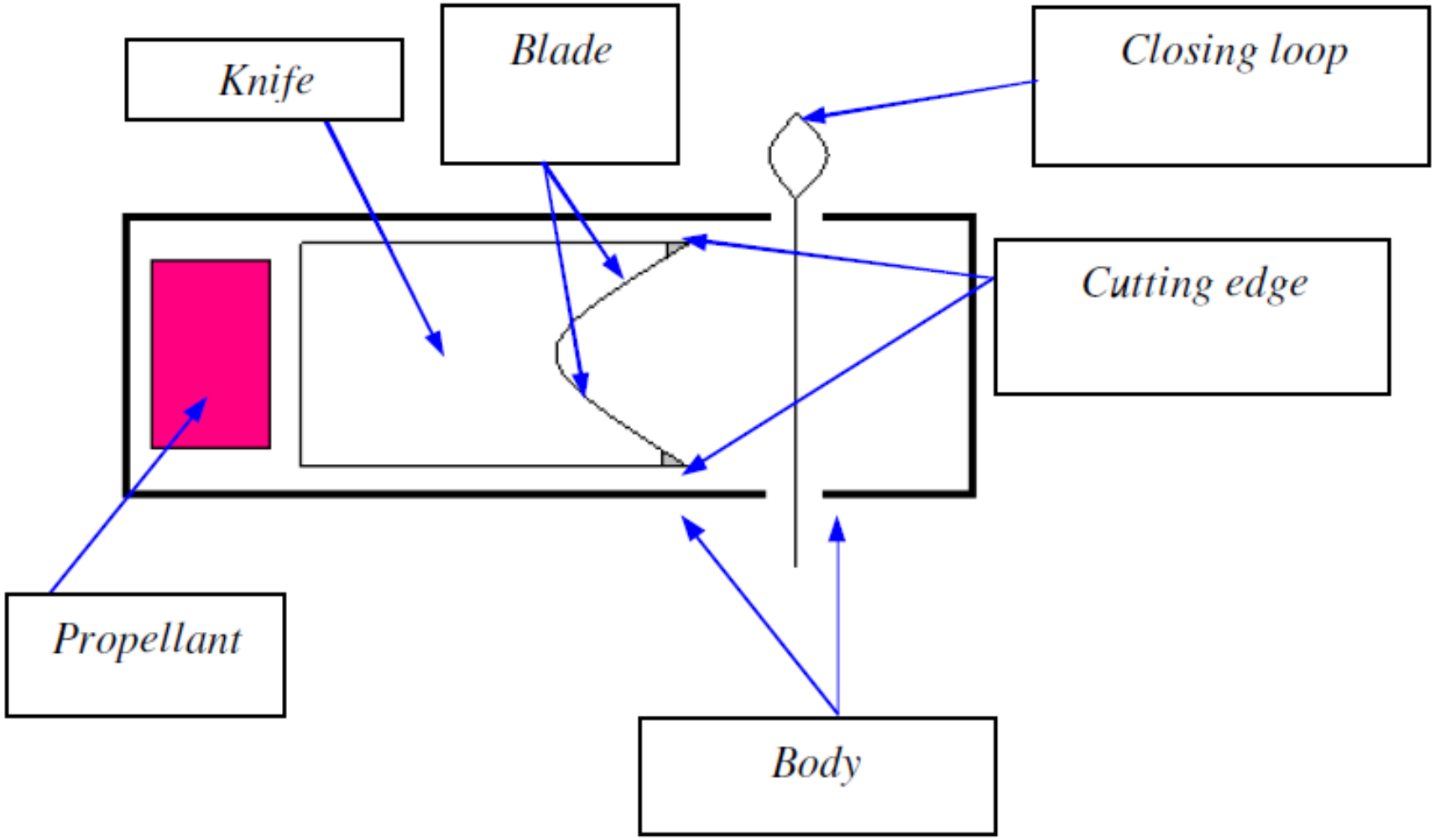
No Pull Incident



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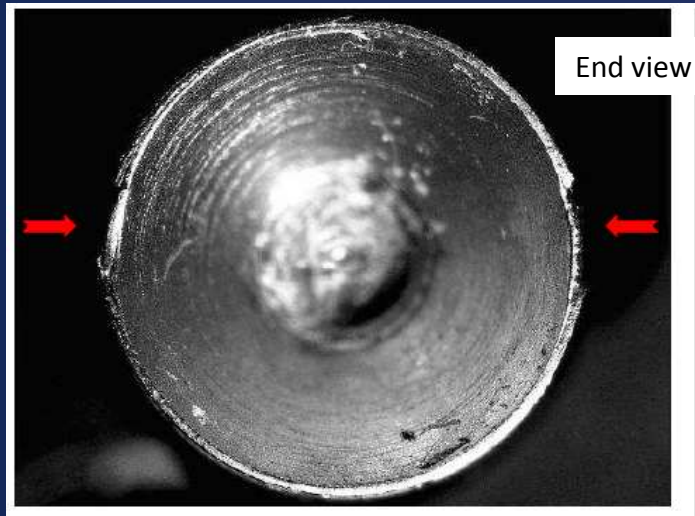
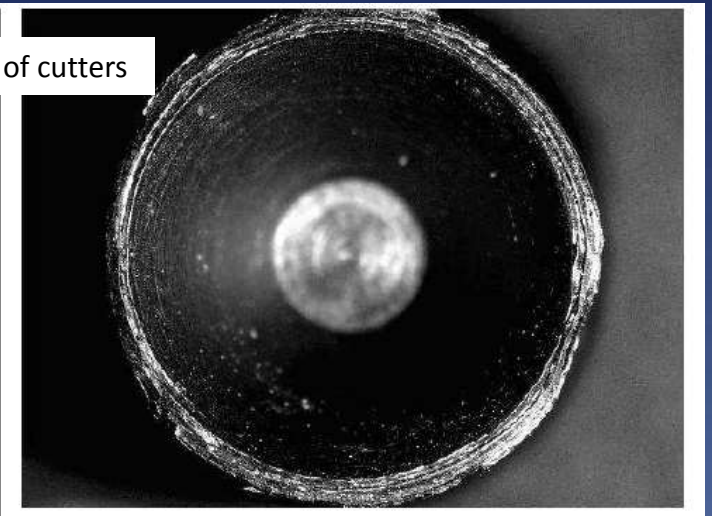
No Pull Incident

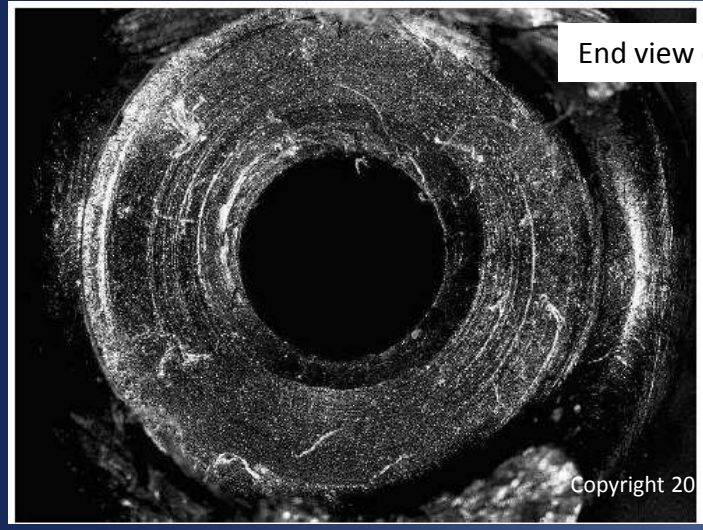


End view of cutters

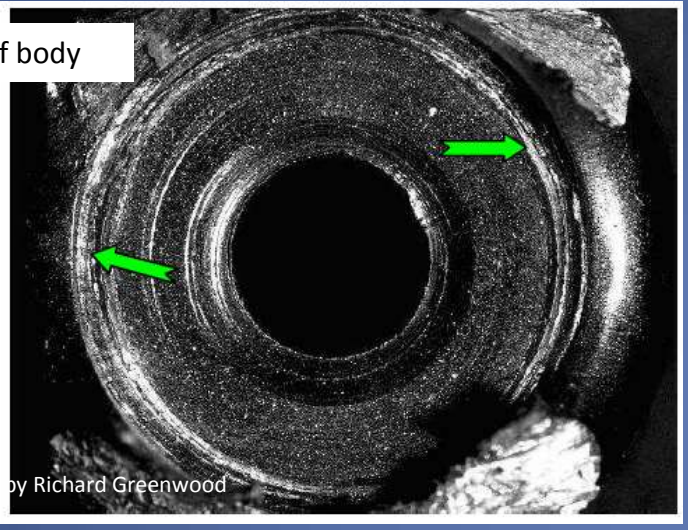


Left, incident Jan 07 Cutter

Right, exemplar Jun 09 cutter



End view of body



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No Pull Incident

Jan 07 Batch

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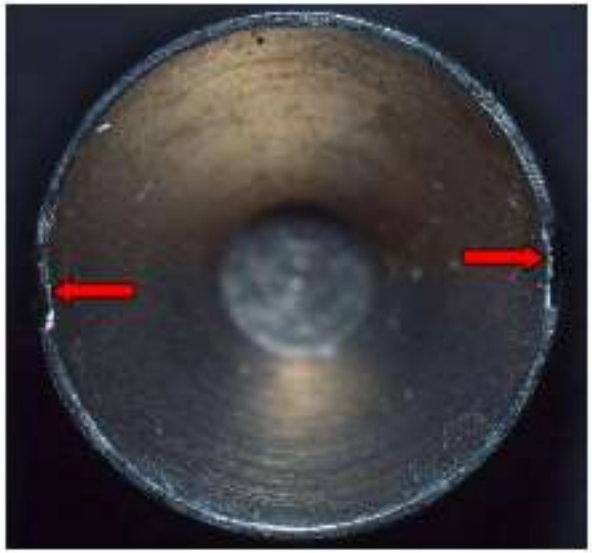
No Pull Incident

Same signatures as incident cutter

End view of cutter



End view of body

Jan 07 Batch

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No Pull Incident

Cutter Metallographic Examination

Jan 07 cutters.
Acicular
Martensite

Jun 09 cutters.
Fine grain
Martensite

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No Pull Incident

Cutter Hardness Examination

Cutter Batch	Vickers Hardness	HRC Hardness
Incident - Jan 07	487	48
Other Jan 07 Cutters	513-531	50-51
Jan 07 Test Cutter	473	47
June 09 Exemplars	594-604	55

The Board determined the proper hardness for this material was Rockwell Hardness of 50-65

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No Pull Incident

- Board Conclusions:
  - Failure of the student to deploy the main parachute for unknown reasons
  - Failure of the student to deploy the reserve parachute for unknown reasons
  - Malfunction of the AAD which resulted in failure to cut the closing loop of the reserve canopy container

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Incident #3
Low Pull

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Low Pull Incident

- Student (Jump #11) Accelerated Free Fall jump from Cessna 208 from 12500 Ft. AGL
  - Coach exited with student but because of fall rate differences could not stay with student
  - Student entered a cloud layer at 6000 Ft. AGL and was not seen by the coach after that
  - Student was found in his harness on his right side lifeless from an evident high speed impact
  - Both the main and reserve parachutes were out of their respective containers but still in their deployment bags with the lines stowed
  - (A first responder had removed the main canopy from its bag to cover the deceased. He also may have removed the main pilot chute from its pouch)
  - Reserve ripcord was 1.5 M from the body
  - Cut-a-way handle was still in place
  - Main closing loop was broken
  - Reserve closing loop was in place and through the AAD cutter but not broken or cut
  - No audible altimeter was found but a visual altimeter was found on the deceased's wrist

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Reserve Ripcord

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Reserve Pilotchute

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Reserve Ripcord Housing

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Altimeter

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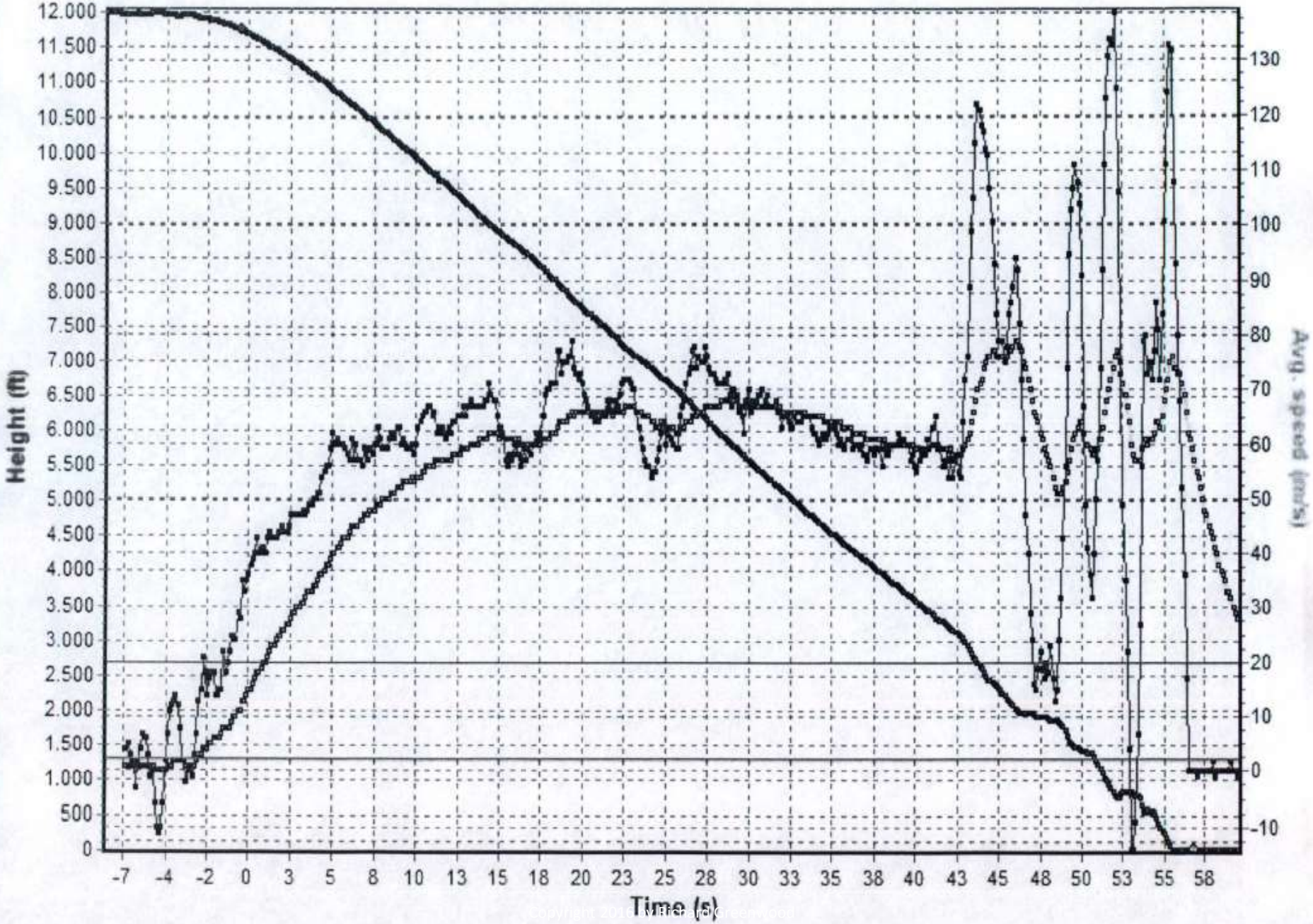

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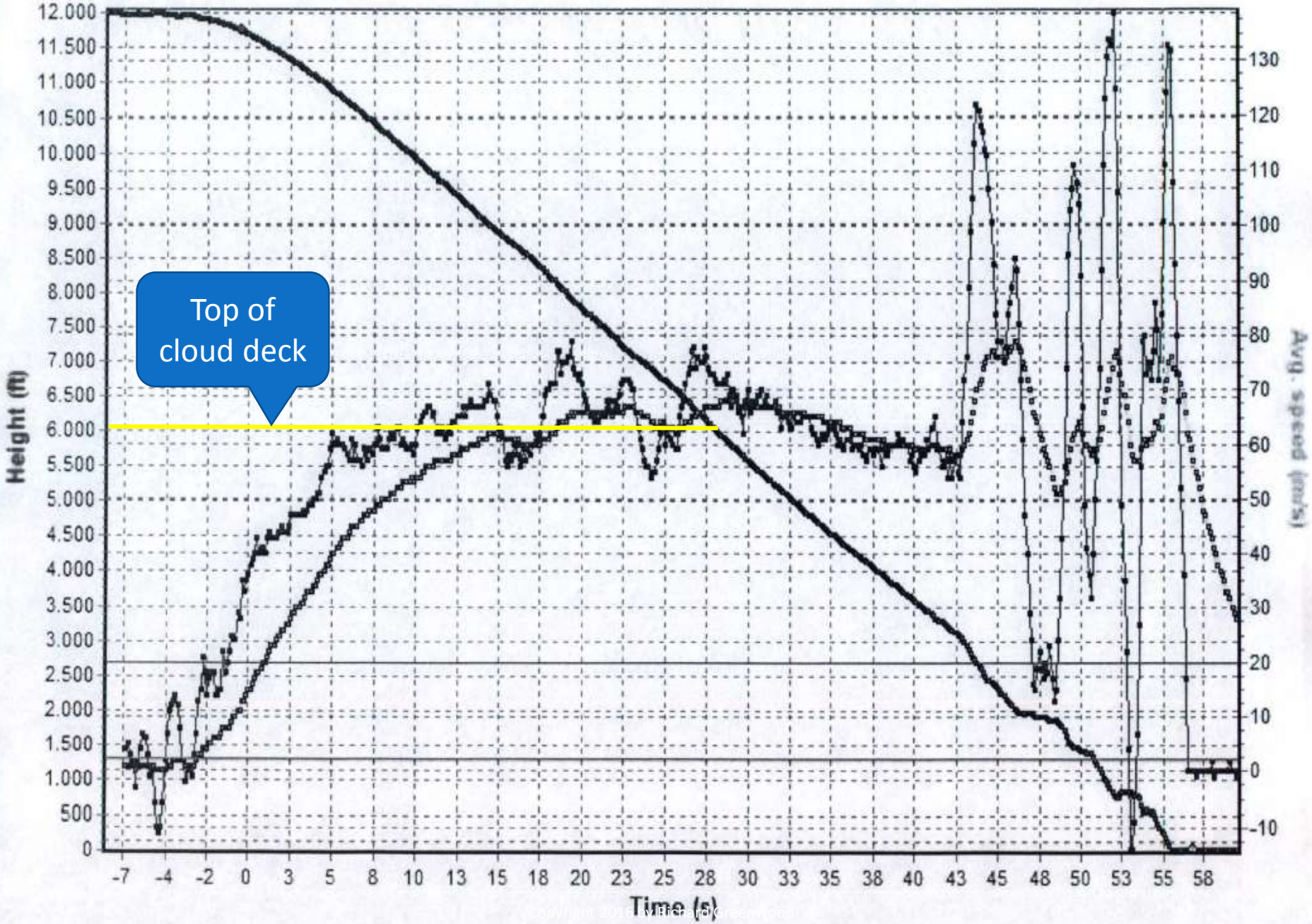

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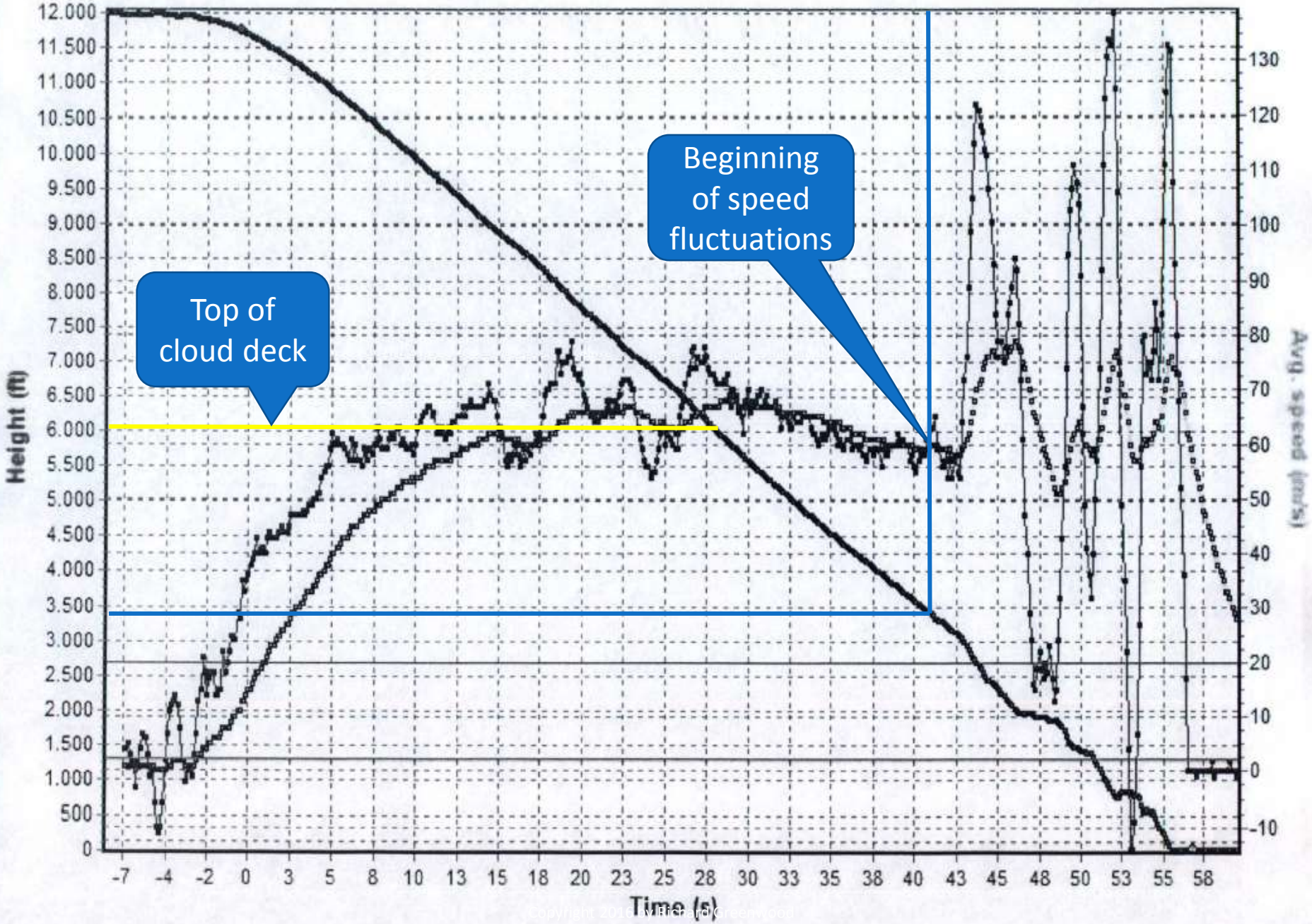

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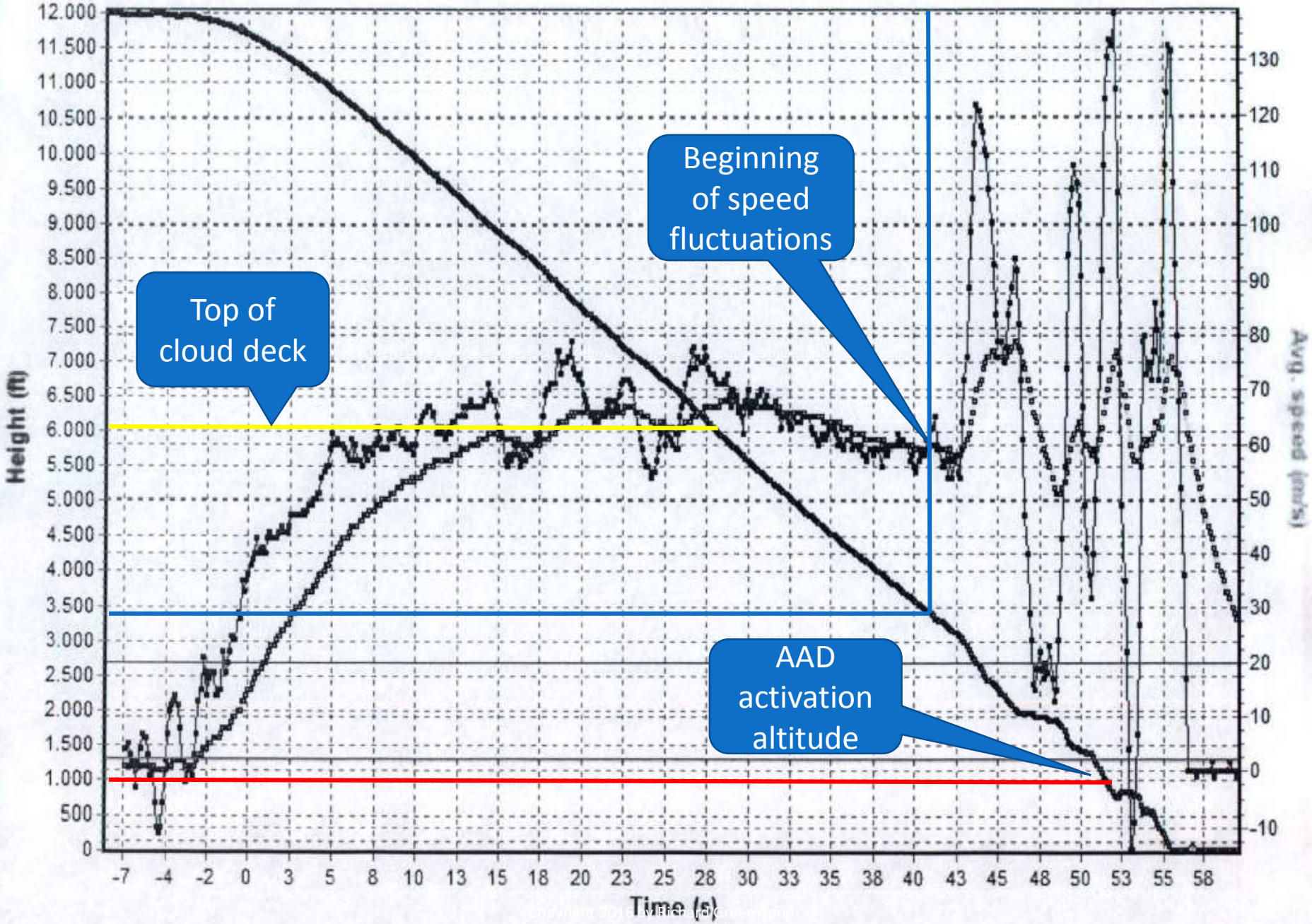

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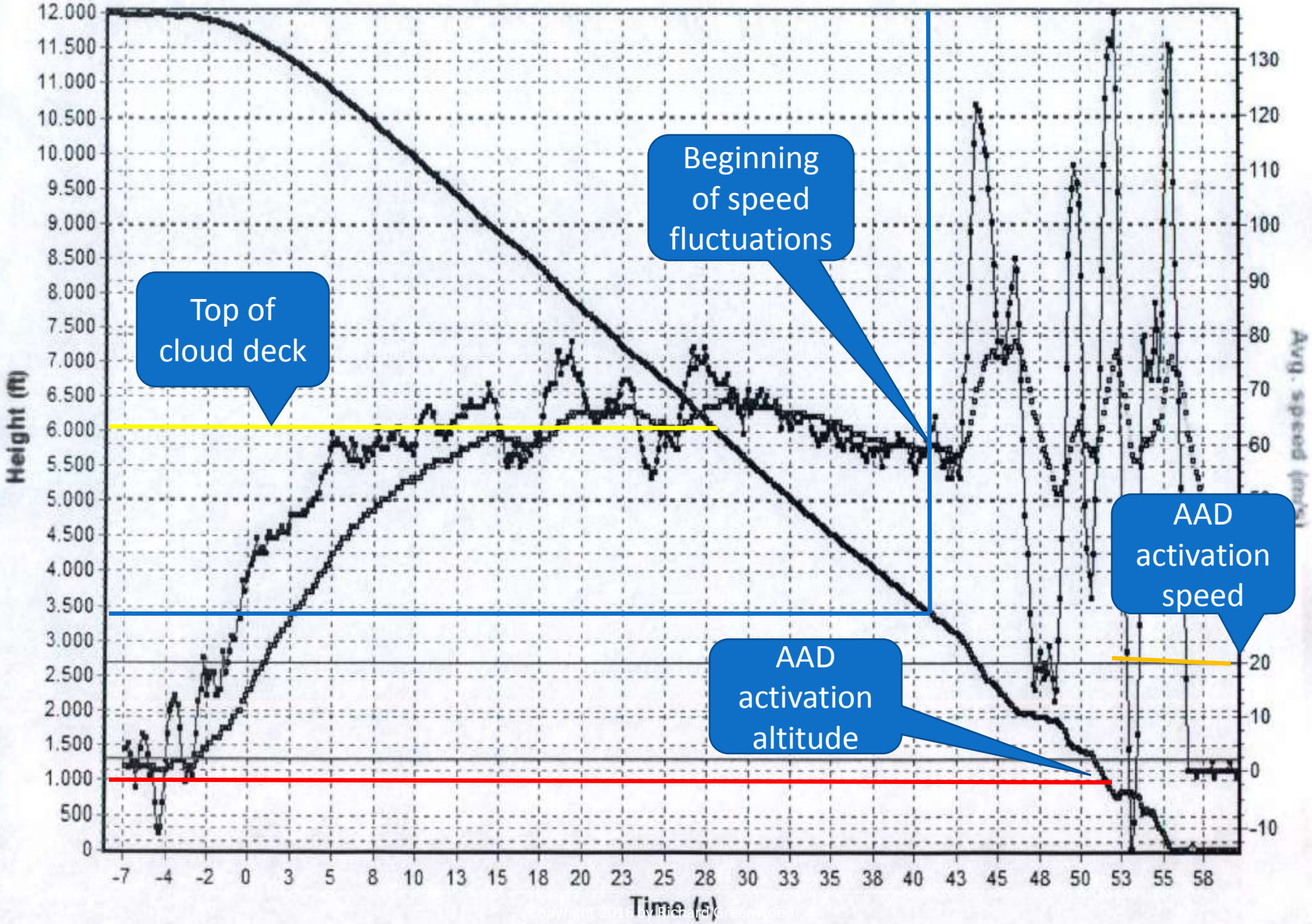

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Reserve Closing Loop

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Reserve Closing Loop

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Low Pull Incident

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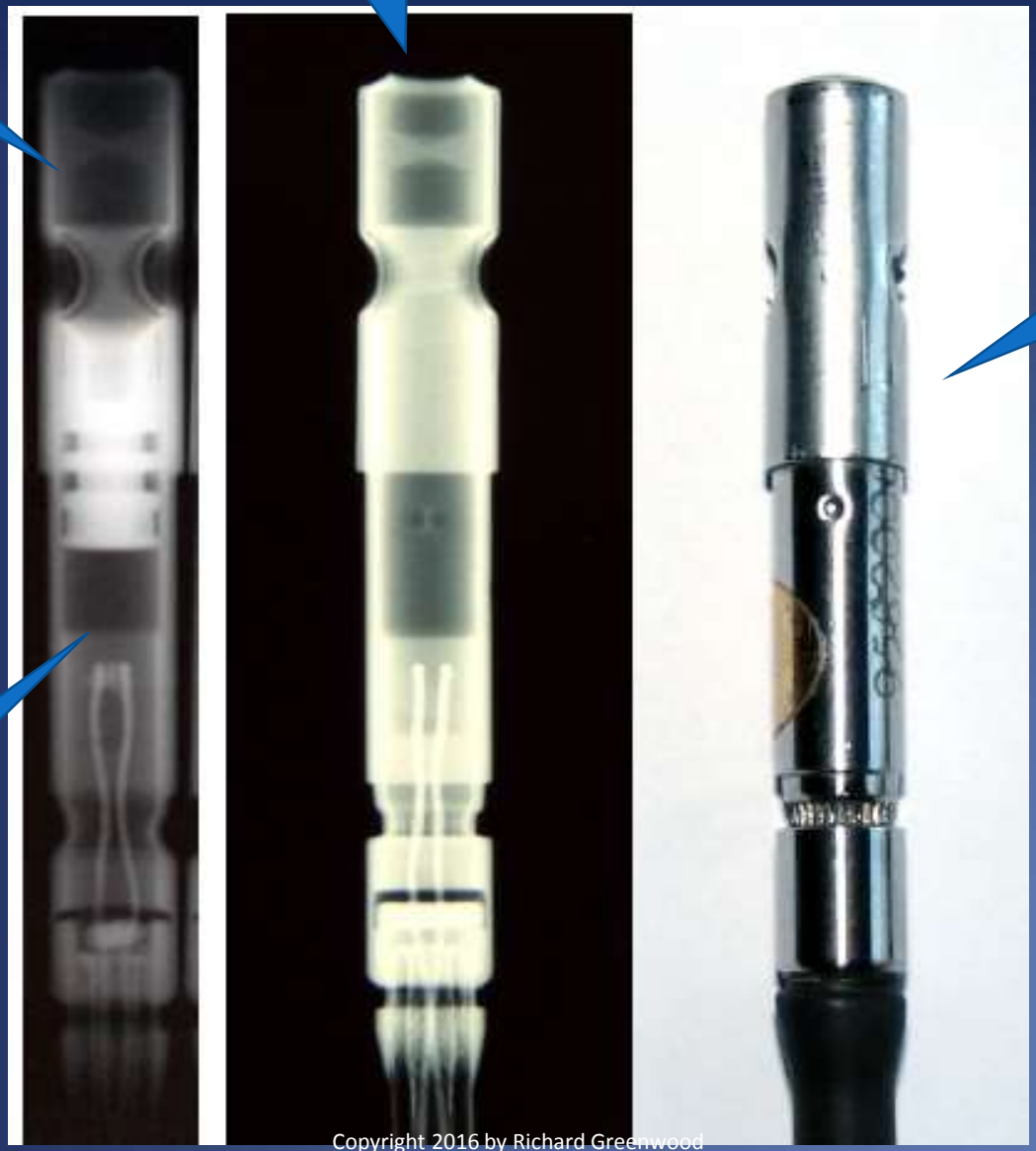
Low Pull Incident



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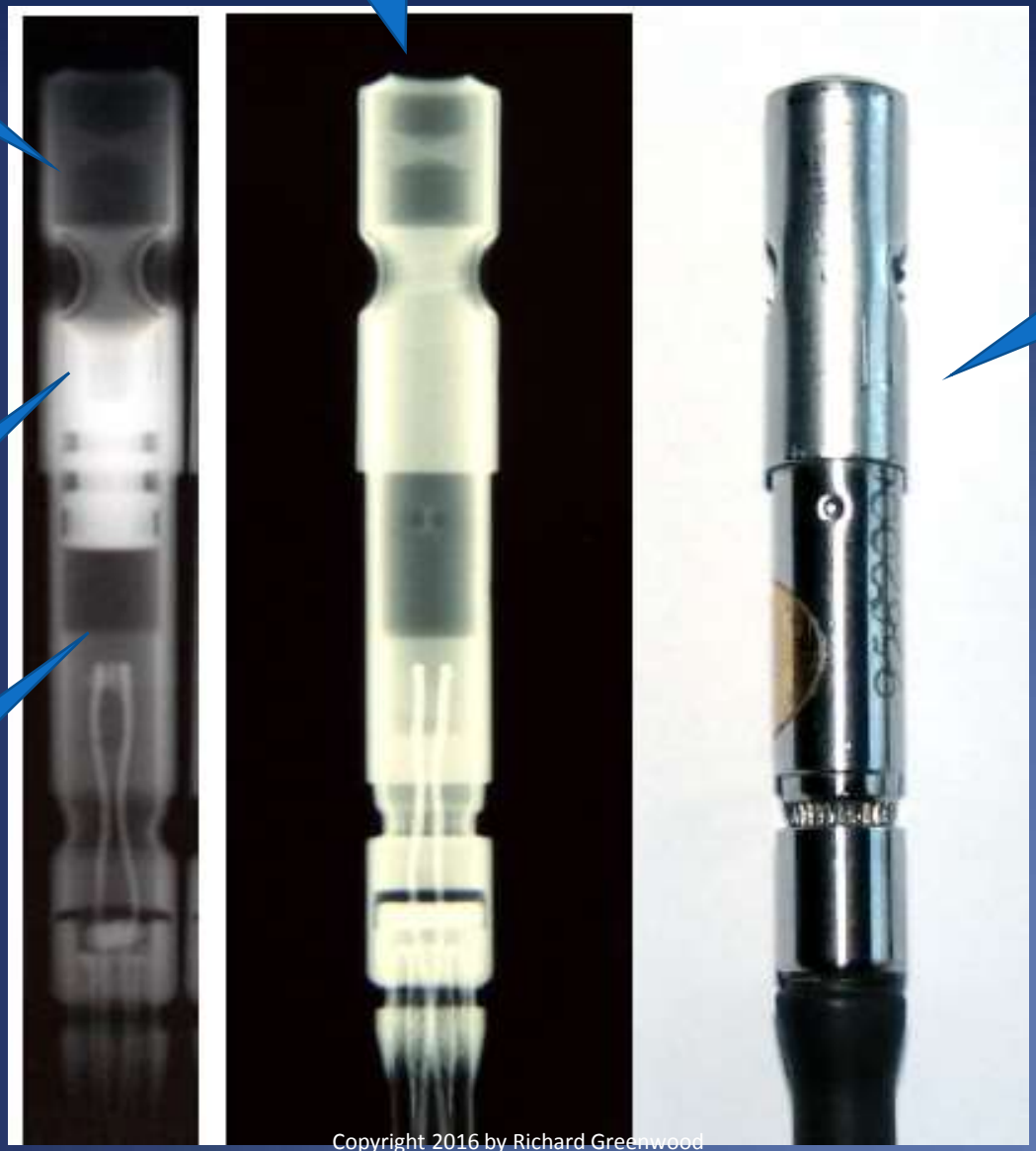

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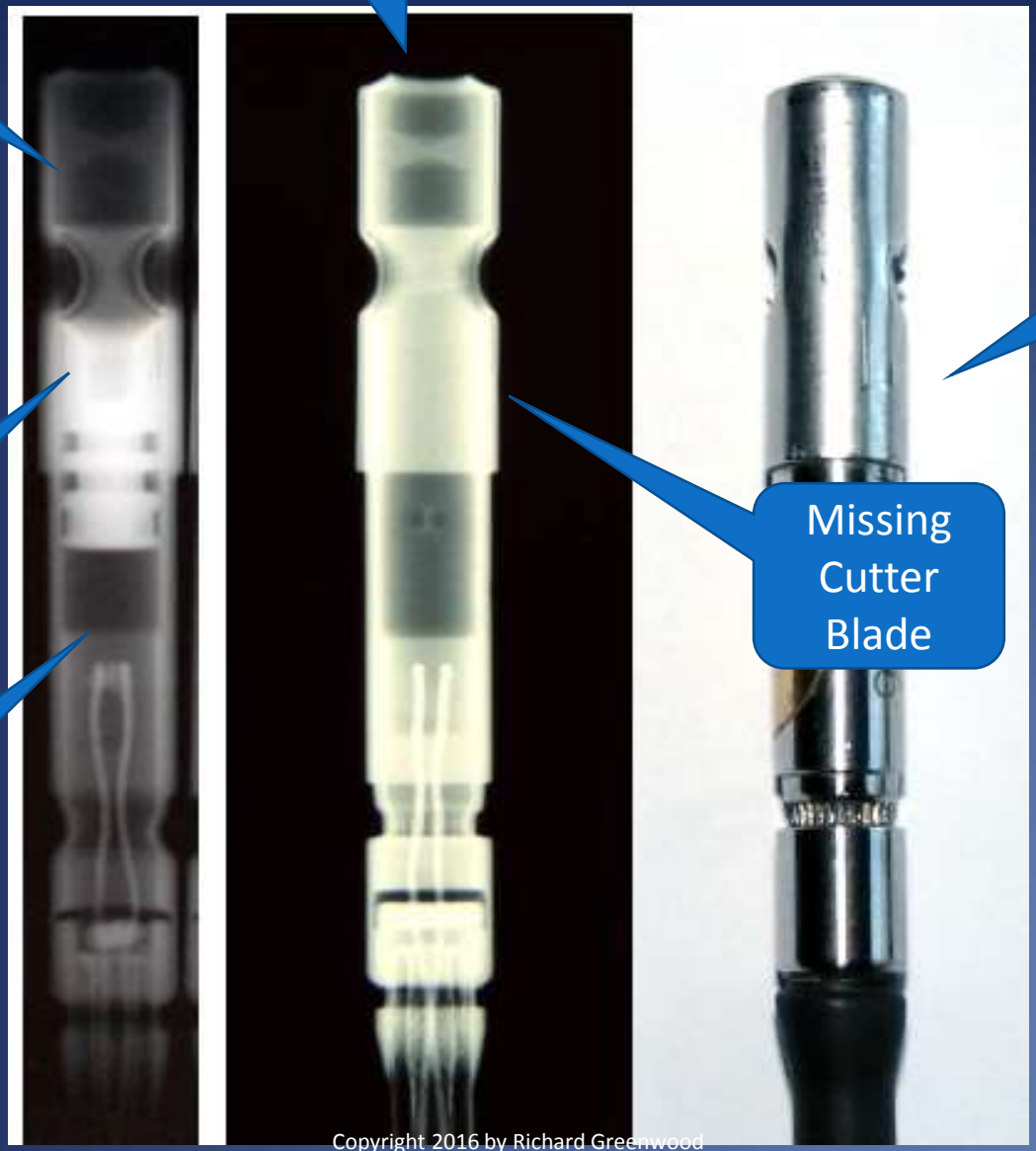
Low Pull Incident



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Low Pull Incident

- Conclusions:
  - Jumper likely became disorientated and unstable at pull time due to being in the clouds
  - Jumper failed to activate his main parachute at an appropriate altitude
  - At AAD firing altitude the AAD activated but lack of cutter blade prevented it from cutting the reserve closing loop and activating the reserve
  - The Jumper most likely manually activated his reserve parachute just before impact

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Questions?

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