



Biomedical Results of the Red Bull Stratos Project

Flat Spin and Negative Gz in High Altitude Free Fall Pathophysiology, Prevention and Treatment

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Disclosure Information

James Pattarini, MD

I have no financial relationships to disclose.

I will not discuss off-label use and/or investigational use in my presentation



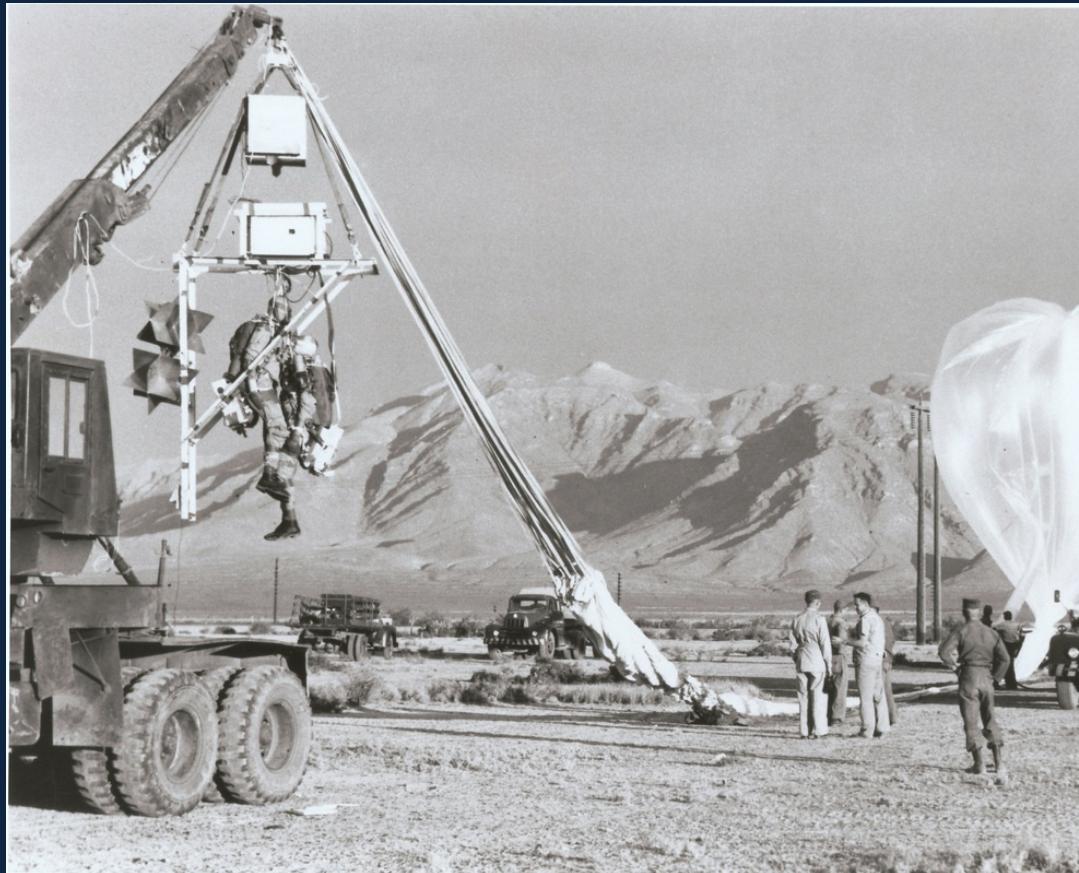
Introduction

- Red Bull Stratos mission profile:
 - Flat Spin: horizontal spin about x-axis of the body
 - Possibility during high-altitude free fall:
 - Relatively low (low chest) center of mass
 - Rarified atmosphere
- Exposure to sustained $-G_z$ acceleration and associated injury patterns
- Goal: Mitigate risk of potentially fatal flat spin
 - Identify spectrum of injury
 - Guide treatment if $-G_z$ exposure occurs



Flat Spin in Free Fall

- 1950s Operation High Dive





Flat Spin in Freefall

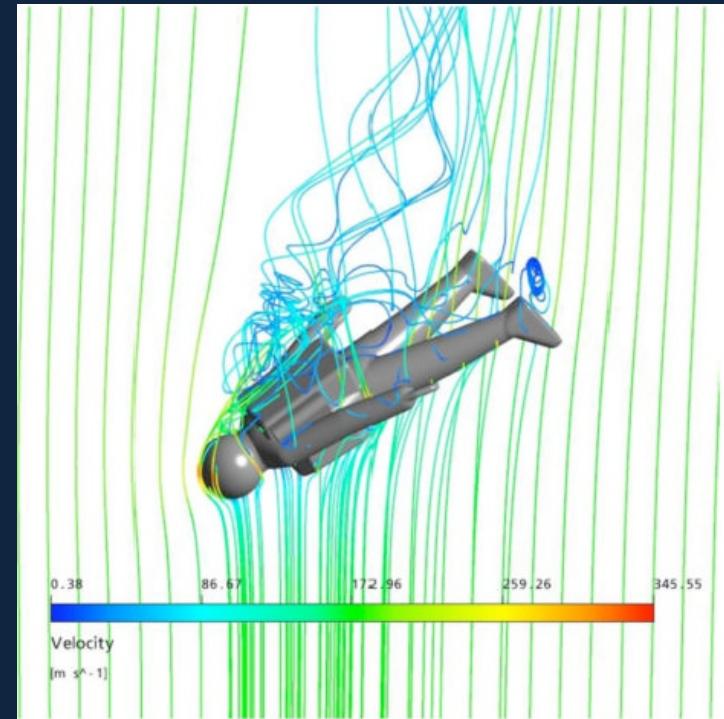
- Even with drogue, risk of spin high
- 1959: Project Excelsior
 - Captain Kittinger: near-fatal spin on descent from 76,400 ft
 - Drogue deployed early, entangled in parachute lines
 - Rotation up to 120rpm





Compounding Risk

- Unique Stratos goals and risks:
 - Maximize acceleration, surpass Mach 1
 - No continuous drogue
 - Egress from untested altitudes
 - Acceleration to untested speeds
 - No vehicular protection
 - Potential for compression wave turbulence in transonic region





Human Tolerance

- Acceleration tolerance limits, injury patterns, established for +Gx (chest-to-back), +Gz (head-to-toe) vectors
- Pressure suit / Life support equipment: low-chest center of gravity
- Flat spin predominant force: -Gz acceleration





Methods

- Literature Review:
 - Human and animal injury patterns from -Gz exposure
- Medical Team -Gz protocol based on literature
 - Prevention
 - Assessment
 - Diagnosis
 - Pre-hospital Treatment



Patterns of Injury

- Cardiovascular Effects
 - Subendocardial hemorrhage, contusion
 - Dysrhythmia
 - Hypotension
- Pulmonary and Respiratory Response
 - Diaphragm displacement, atelectasis
 - Vagal stimulation: venous pooling, edema
 - Pulmonary shunting
 - Petechial hemorrhage, microthrombi
- Ocular and Periocular
 - Visual disruption, nystagmus, blurring, loss of acuity, subconjunctival hemorrhage
- Cerebral Effects
 - Venous pooling, edema
 - Mental slowing
 - Subjective: confusion, pain, nausea, vomiting



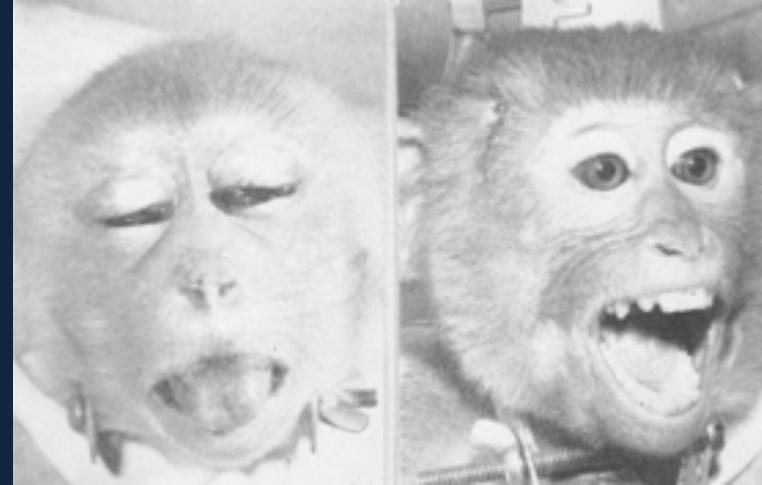
Gauer 1950





Cerebral

- Blood volume shift towards head
 - Volume sufficient to force constricted vessels open
- Decreased venous return
 - Cerebral blood stagnation (local hypoglycemia)
- Animal models:
 - Cerebral edema
 - Subarachnoid hemorrhage
 - Focal demyelination, gliosis
 - EEGs: delta rhythms, acute brain injury



Beckman 1956





Prevention

- Training
 - Careful exit from capsule to avoid inducing spin
 - Bungee Step-Off Tests
 - Corrective limb movements in rarified atmosphere:
 - Destabilization
 - Worsening spin
 - Parachutist trained to maintain “delta position”



Bungee Step-Off





Delta Position





Prevention: Instrument Pack Positioning

- Instrument pack position:
 - Dictates body position
 - Project Excelsior: instruments strapped to body as “chair”
 - Delta position impossible
 - Affects center of mass
 - Goal: impart minimal –Gz
 - Shift center of mass towards head
 - Final center of mass approximately heart/low sternum

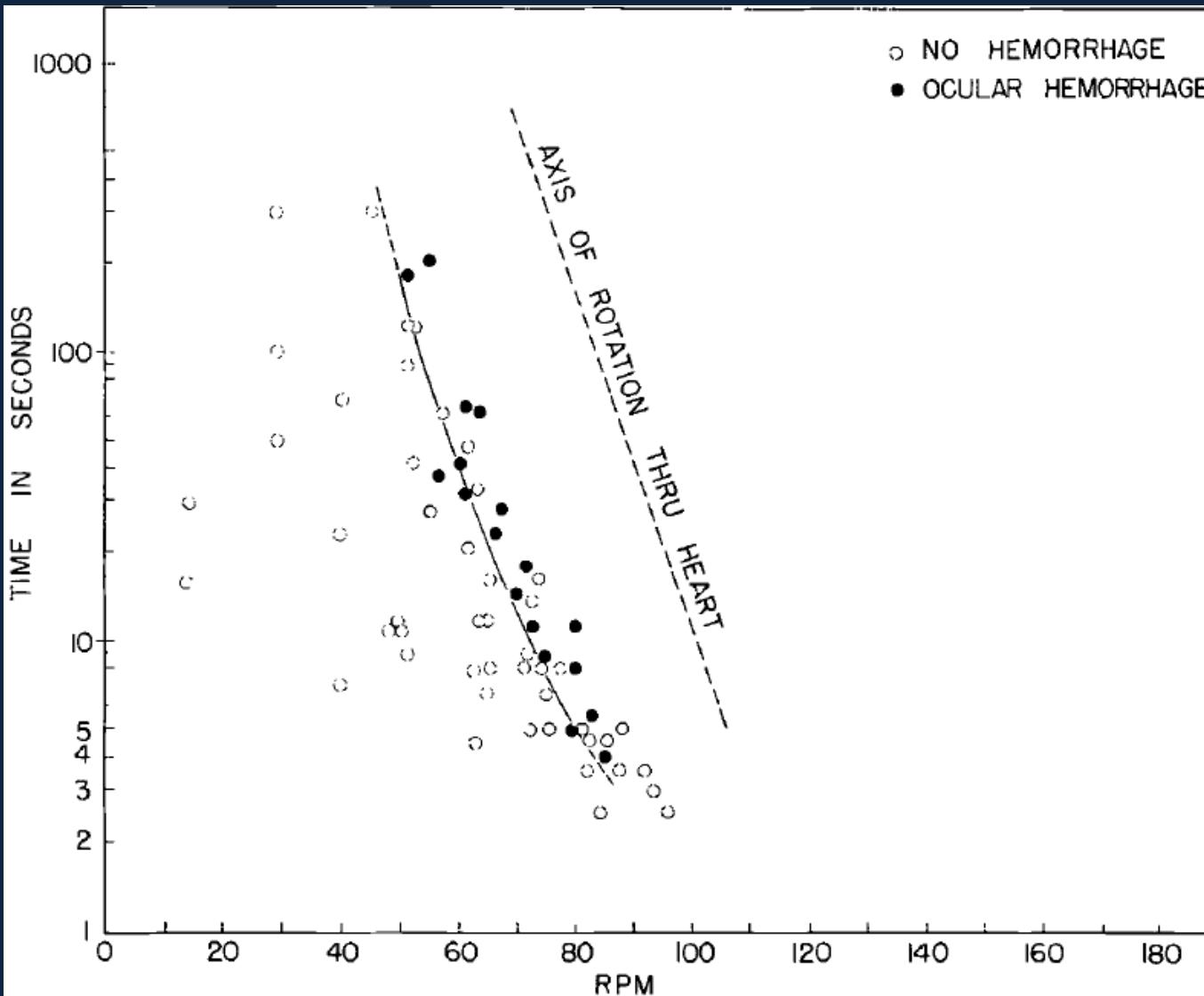


Prevention: Instrument Pack Positioning





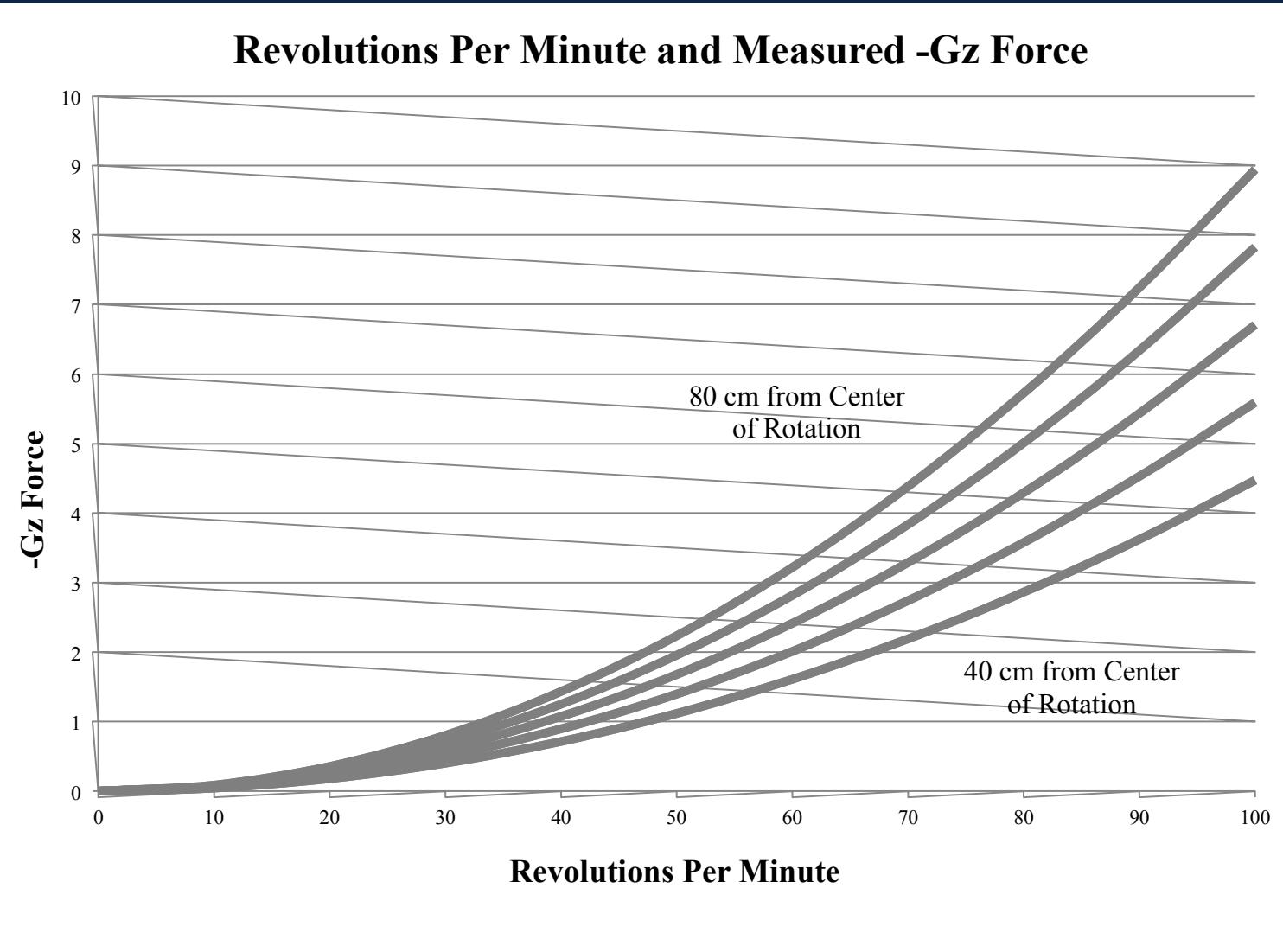
Flat Spin Human Studies



Spin is more tolerable when Center of Rotation (CR) is at the chest rather than the abdomen



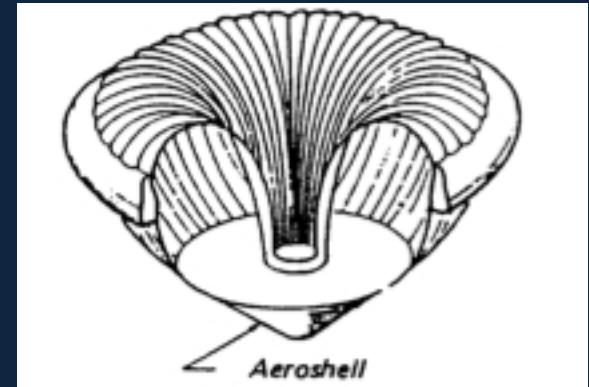
Results





Prevention: Spin Avoidance and Recovery

- Ballutes: supersonic munitions stability
 - To achieve enough drag:
 - Ballutes very large
 - Pair with Drogue
- Ram-air fin
 - Unstable during inflation
 - Performance depends on body position
 - No transonic validation





Ram-Air Fin





To Drogue, or Not...

- Drogue design:
 - Ribless Glide Surface Drogue validated to Mach 1.4
- Attachment points:
 - Initially attempted to maintain delta position (waist/hip attachments)
 - Did not fully stabilize flight – continued spin possible
 - High-shoulder attachment
 - 100% reproducibility
 - Terminates spin >90rpm

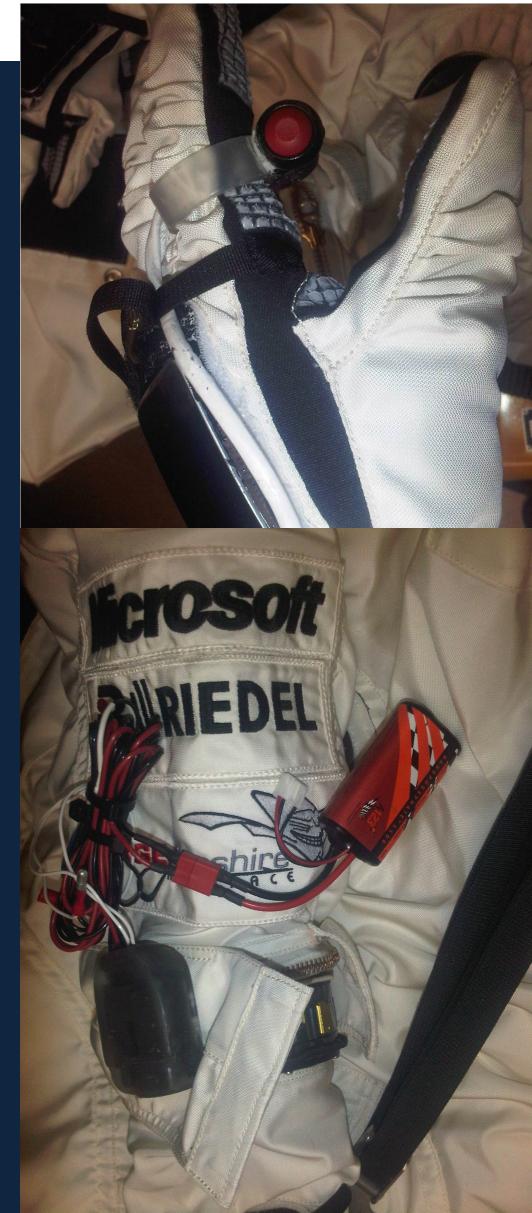






G-Whiz Development

- G-Whiz: triggering device
 - Automatic drogue deployment
 - -3.5Gz sustained >6 seconds
 - Subjective loss of limb control
 - Unable to manually deploy drogue
 - 38 second delay
 - Prevent drogue failure, potential for entanglement
- Nominal: no drogue
- Contingency: manual or automatic drogue deployment





Medical Protocol: Recognizing Injury

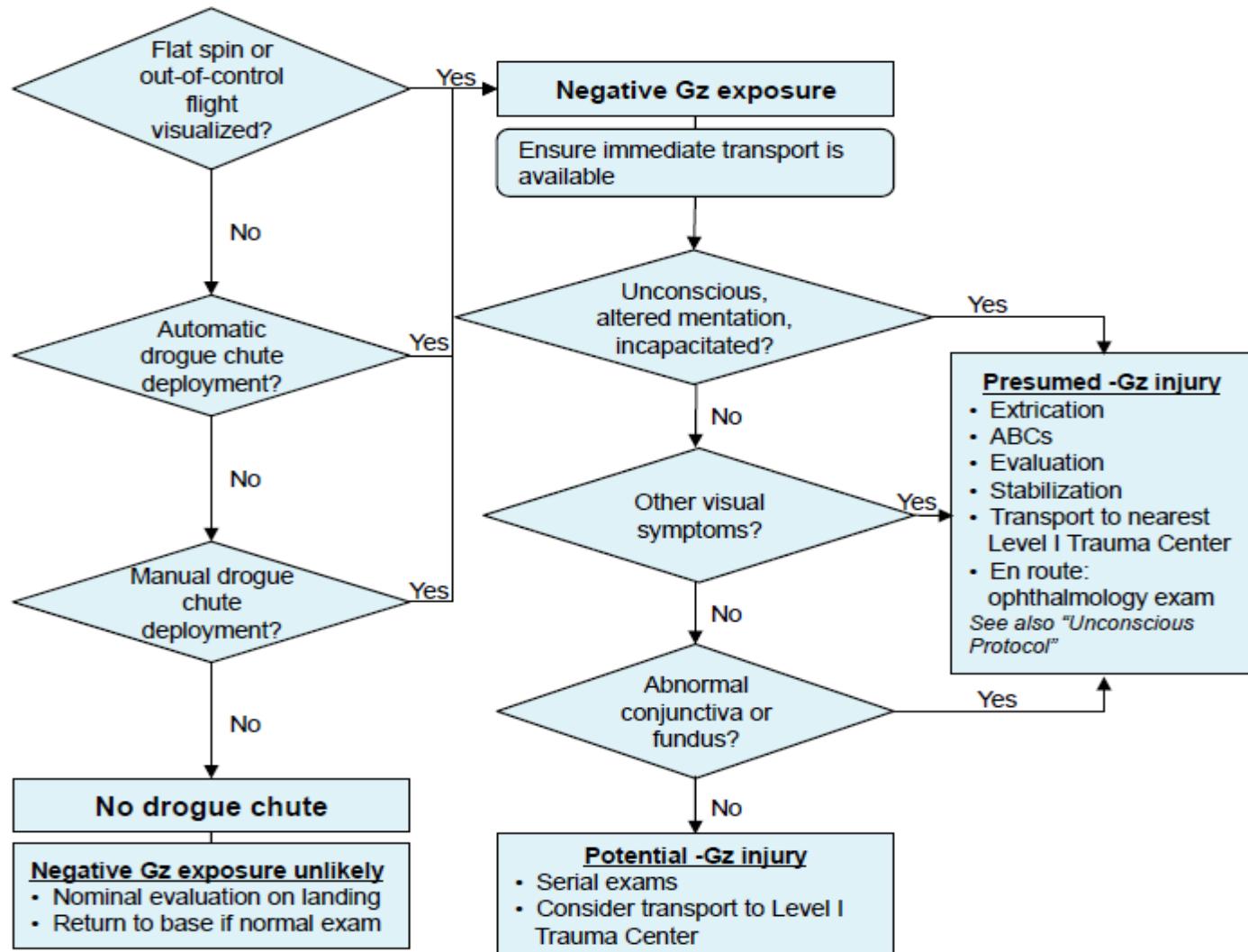
- Ground Videography
 - Drogue deployment
 - Parachutist body position
- Communications
 - Verbal confirmation
- Suggestive or pathognomonic findings
 - AMS, incapacitation
 - Isolated visual symptoms
 - Abnormal conjunctiva or fundus on exam





Medical Protocol

Negative Gz Protocol





Manned Flight 3 Spin

- Final high-altitude jump October 14, 2012:
 - Flat spin appx 40 seconds into free fall from 127,852 ft
 - Unstable flight followed by rotation about x-axis
 - Maximum exposure: 60rpm (-2Gz at head level)
 - 35 seconds before stability reestablished

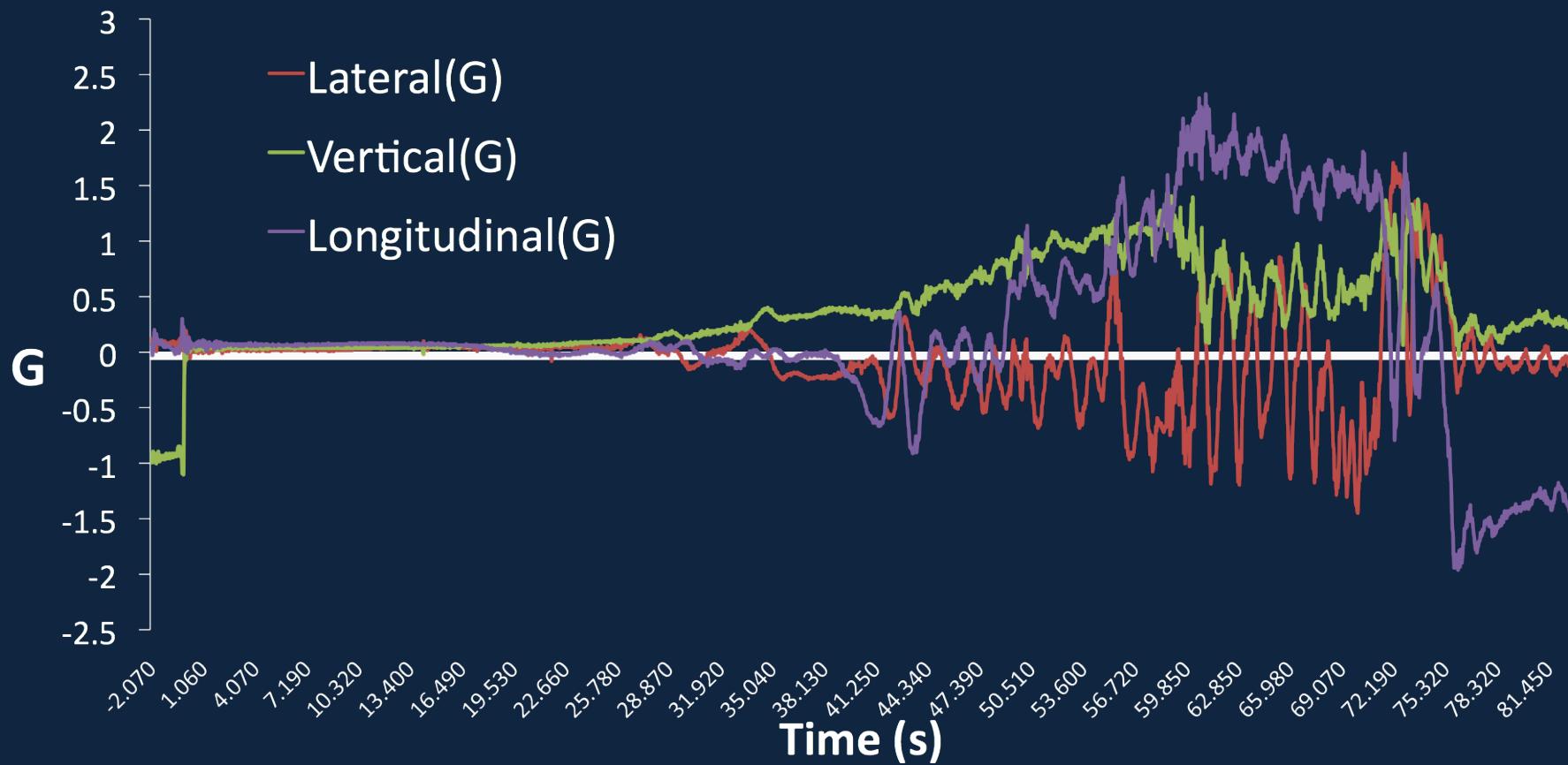


Discussion

- This spin was not severe enough to trigger the drogue
 - Able to maneuver throughout
 - Reported minimal discomfort
 - Able to recover stable flight with body position in thickened atmosphere
 - Ophthalmologic exam normal on landing
- “Worst case scenario” (unrecoverable spin) not encountered
 - Destabilized flight demonstrated that concerns were warranted



Triaxial Acceleration in Spin





Summary

- Severe rotational acceleration
 - Potential for cardiovascular and intracranial injury is high
 - Cerebral Edema
 - Subarachnoid hemorrhage
 - Dysrhythmias, asystole
- Medical protocol
 - Address prevention first!
 - Careful training
 - Mitigation strategies
 - Recognize Injury
 - Transport and Treat





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